LVII.—On "Eozoon Canadense." By Professors William King, Sc.D.; and Thomas H. Rowney, Ph. D.; of the Queen's University in Ireland, and the Queen's College, Galway.

[Read July 12, 1869.]

CONTENTS.

1. *Introduction.*

The first observation that gave rise to the idea of the subject of the present Paper being a fossil organism was made, in 1858, by Sir William E. Logan, Director of the Geological Survey of Canada, who was struck with the resemblance of specimens, consisting of alternating lamellæ of white pyroxene (malacolite) and calcite, to the fossil coral, *Stromatopora*, common in the Silurian rocks. The specimen was from one of the calcareous beds of the Laurentian system, at the Grand Calumet, in Canada. Some years previously other specimens from a different part of the same region, similarly laminated, had been brought to Sir William Logan: these, however, consisted of layers of loganite—(a mineral related to serpentine) and dolomite. The Director remarks—" If specimens from both these places were to be regarded as the result of unaided mineral arrangement, it appeared to me strange that identical forms should be derived from minerals of such different composition."*

Drs. Dawson and Sterry Hunt having had their attention called to these specimens, and others found abundantly in the Laurentian ophites of Canada, in which serpentine takes the place of the precited mineral silicates, the latter made a chemical and mineralogical investigation of them, and the former undertook to examine their structural characters. The result was, that both investigators pronounced the specimens to belong to a " fossil." From occurring in rocks the oldest of any known—older than any which geologists on this side of the Atlantic were properly acquainted with, and seeming to be in relation with the " first appearance of animal life on our planet,"

* "Quarterly Journal of Geological Society," vol. xxi., p. 48.

Dr. Dawson distinguished the "fossil" by the generic name "*Eozoon*" or "dawn animal;" and called it specifically "*Canadense,*" to denote its occurrence in Canada.

Specimens brought to London by Sir W. Logan were placed in the hands of Dr. Carpenter, who shortly after prepared a Paper, which, along with others, written by the Director of the Canadian Survey, Dr. Dawson, and Dr. Sterry Hunt, was published by the Geological Society of London.* Dr. Carpenter was enabled to bring to light some additional details of a most important character, which not only confirmed, as he conceived, the view held by Dr. Dawson, that "*Eozoon Canadense*" was a gigantic foraminifer, but showed, in his opinion, that it belonged to the most complex section of its class.

The discovery of presumed foraminiferal remains in rocks that correspond in many respects with the ophites or green marbles of Connemara, led us to imagine that the latter might contain a similar "fossil," establishing thereby their geological age. We were thus induced to enter on an investigation, which it is exceedingly probable would not have been undertaken had not one of us been in possession of a first-class binocular microscope, inasmuch as any researches of the kind carried on with an ordinary instrument are of very little use in determining the character of the different structures to be observed.

The various stages of our investigation need not be dwelt on here; suffice it to say, that, from being firm believers in what had been taken to represent an organism, we became in the end decided unbelievers.† After fully satisfying ourselves as to the truth of the view that had slowly and gradually forced itself on our convictions, we prepared, in 1865, a Paper on the subject, which was read before the Geological Society of London, and published in its "Journal."‡

It is now necessary to give a general description of the so-called "fossil."

The rocks containing "*Eozoon*" are ophites — that is, such as essentially consist of intermixtures of serpentine (composed of a hydro-magnesian silicate, also other allied minerals), and calcite or dolomite. There are two varieties: one has the serpentine in segmented grains or granules scattered irregularly through the calcite. This is called the "acervuline" variety. In the other the serpentine is in segmented plates or layers, here and there confluent, and interlaminated with the calcite. Various modifications of these two varieties occur; and specimens are common, showing the passage of one into the other. In the" eozoonal" ophites of other countries the acervuline is the ordinary variety; and we have reason for believing that this is the case in

* "Quarterly Journal of Geological Society," No. 81, Feb. 1865.

† An announcement of the change in our view appeared in the "Reader," June 10, 1865, p. 660; and in the next number a not over-temperate attack was made upon us by Dr. Carpenter.

‡ "Quarterly Journal of Geological Society," vol. xxii., August, 1866.

Canada. Out of the latter region, however, the laminated one appears to be very rare.

Entire specimens of the laminated variety have been found some inches in thickness, and several in diameter, which has given rise to the idea that individuals of "*Eozoon Canadense*" grew during some (the early) portion of their life by the addition of tier upon tier of "chambers" or "cells;" but as many specimens show this variety, with the presumed representatives of the latter parts, breaking up and becoming scattered through the calcareous matrix, it has been considered that the "acervuline" mode of growth supervened.

In "eozoonal" *parlance* the calcareous portion is named the "intermediate" or "supplemental skeleton;" while the granules and plates of serpentine are called "chamber casts," on the view that they were originally *cavities* in the skeleton, tenanted by the sarcode-divisions of the animal, and which had become filled up with a mineral deposit.

To examine specimens with a high magnifying power, it is necessary to decalcify them with weak acid, or to prepare thin sections. By the first process the calcite disappears, leaving the serpentine untouched. The interspaces between the granules and plates of the latter mineral are now seen to be in numerous instances crowded with a great variety of simple and arborescent vermicular shapes, composed of the same, or a related silicate: some are attached to the granules; and others still remain imbedded in the undissolved portion of the "skeleton," seemingly independent of the "chamber casts." These structures were first detected by Dr. Dawson, who, supposing them to be casts of tubes, such as belong to the "canal system" excavated in the "intermediate skeleton" of certain genera of foraminifers, considers them to represent the same part in "*Eozoon*." Applying a high power to the serpentine granules, &c., they are often seen to be covered with a white glistening asbestiform layer, the fibres being frequently at a right angle, and occasionally oblique, to the surfaces to which they are attached. The fibres in many cases have a striking resemblance to casts of the perforations or minute tubuli belonging to the "true wall" of the *nummuline* foraminifers (in which the perforations admit of the extrusion of the sarcodic extensions, called pseudopods); and they have consequently been considered by Dr. Carpenter, to whom is due the chief merit in discovering them, to represent the "nummuline layer."

The object of our Paper was to show that every one of the structures diagnosed for "*Eozoon Canadense*" by Dawson and Carpenter is purely of inorganic origin. We maintained that the "*chamber casts*" are simply granules of serpentine—as much mineral products as the grains of chondrodite, pargasite, &c., common in certain rocks; that the "*intermediate skeleton*" is their calcareous matrix, as is the calcite in which the latter minerals usually occur; that the branching shapes, which constitute the "*canal system*," and penetrate the matrix, are nothing more than forms of metaxite, or some allied mineral, also oc-

curring in micro-crystalline calcite; and that the "*nummuline layer*,' coating the serpentine granules, is a film of chrysotile in various states of modification. Metaxite and chrysotile we showed to be mere allomorphs of serpentine, being the same hydro-magnesian silicate, under other forms besides the amorphous, that characterizes the latter: the three correspond to the fibrous, branching, and amorphous varieties not unusual to calcareous, siliceous, and some other minerals.

Moreover, "eozoonal" structures were shown to have *never been found except in crystalline or metamorphic rocks*, especially those containing serpentine, or some of its varieties; and to occur under these conditions in deposits of widely different geological ages—not only in the Laurentians, but in others that are members of later systemal periods, even in the serpentine or crystalline marbles belonging to the Liassic system.

The "fossil" we are engaged with has obtained sufficient notoriety as a disputed body, and it is of so much importance in geology, irrespective of whatever view may be taken of it, as to require from all who are interested in the truthful progress of this science extremely careful consideration, and the most searching investigation. Yet the late President of the Geological Society, Mr. Warrington W. Smyth—who declared that "the grandest feat of geological science within the last few years is the astounding extension of the scale of geological time consequent on the discovery of '*Eozoon Canadense*'"—has set aside a "*fact*" of considerable weight for a mere *unsupported announcement.* "The elaborate arguments of Messrs. King and Rowney in favour of the mineral origin of 'eozoonal' structure *had at one time a strong show of support* in the fact that these appearances" (structures) "were always observed in *serpentinous* limestone (ophicalcite) only, whether in Canada, Connemara, Tyree, Bavaria (Dr. Gümbel), or Bohemia (Dr. Von Hochstetter), notwithstanding great discrepancy in the age of some of the deposits. But the *announcement* made by Dr. Carpenter in the 'Quarterly Journal of the Geological Society for August last (1865),' of Dr. Dawson's discovery of '*Eozoon*' preserved in carbonate of lime pure and simple, would appear to close the discussion."*

In the present communication it is our intention to review all the arguments and evidences, including statements made in connexion with the above announcement, that have been brought forward since our Paper was published; and we shall adduce additional proofs against what Dr. Carpenter calls the "received doctrine." Moreover, Connemara abounds with rocks yielding some of the most beautiful marbles known, and composed to a considerable extent of "*Eozoon Canadense*"—a fact which may be held of additional importance in inducing the Royal Irish Academy to take a part in promoting the settlement of the question as to the origin of this so-called "fossil."

* Anniversary Address to the Geological Society. See "Quarterly Journal of Geological Society," vol. xxiii., p. lxiv.

Before entering on the several points treated of in the following sections, we deem it necessary to make a few remarks on the principal communications that have lately appeared on the subject.

The Director of the Geological Survey of Bavaria, Dr. Gümbel, brought out a Paper* about the same time as ours appeared, which is remarkable on account of the way the author has treated the subject, and in confirming many of our statements. Dr. Gümbel, following the same line of argument as we did through its legitimate channel, compares the different "eozoonal" structures with certain well-known forms (some of which were cited by ourselves) of mineral silicates imbedded in crystalline limestones; but, as an unquestioning belief in "*Eozoon*" eminently distinguishes his Paper, he quite consistently regards as organic the forms which we showed to be mineral products.

Dr. Carpenter has published two contributions; also some "Notes" appended to a communication by Dr. Dawson, shortly to be noticed. The earliest one, entitled "Supplemental Notes on the Structure and Affinities of *Eozoon Canadense*,"† which immediately follows our Paper, may have been written as an answer to the evidences and arguments we adduced; but, with the exception of *two or three paragraphs* at the end, and a *few foot notes*, it is principally an elaborate *résumé*, and in many cases a *verbatim* copy, of a previous memoir by himself in the "Intellectual Observer," every point of which was discussed, and we believe invalidated, or disproved by ourselves: as to the additional matter, we shall have to notice it hereafter. The next Paper, with a similar title to the above, appeared as a "Letter to the President of the Royal Society."‡ Anything new comprised in it, and in the "Notes" appended to Dr. Dawson's communication, will be so fully treated of in another place as to render a notice of them unnecessary at present.

Dr. Dawson's Paper, entitled "Notes on Fossils recently obtained from the Laurentian Rocks of Canada, and on Objections to the Organic Nature of Eozoon,"§ is principally taken up with a description of a "Specimen of Eozoon from Tudor," and a few more, assumed to exhibit "eozoonal" features, from other localities in Canada. The account of the first of these specimens will be considered shortly. Dr. Dawson's criticisms on our "Objections to the Organic Nature of Eozoon" are uncommonly brief, scarcely occupying three pages; and, as a consequence, they leave untouched much of what is contained in our "elaborate attempt;" the reason for such brevity being, as stated, that the Tudor specimen "furnishes a conclusive answer" to our "objections;" and that Dr. Carpenter "has already shown their inaccuracy in many important" points—we presume in the "Supplemental Notes." The same "fossil" has also received some notice from Sir William Logan,

---

* "Ueber das Vorkommen von Eozoon in dem ostbayerischen Urgebirge," 1866.
† "Quarterly Journal of Geological Society," vol. xxii., pp. 219–228.
‡ "Proceedings of the Royal Society," vol. xv., pp. 503–508.
§ "Quarterly Journal of Geological Society," No. 91, August, 1867, pp. 257-264.

in his Paper "On New Specimens of Eozoon,"* published at the same time as Dr. Dawson's.

We shall now proceed to examine the specimen from Tudor.

In the first place, the "fossil," which has the general appearance of a Fenestella (not that we have the least suspicion of its having any relation to the latter, or any other organism whatever), is exceedingly thin, and consists of a number of parallel or sub-parallel slender string-like ribs, strangely called "septa," lying in one plane; which ribs "divide and reunite at short distances:" a "few transverse plates, or connecting columns, are visible;" otherwise the so-called *septa* "do not coalesce," except on one of its sides. Taking Dr. Dawson's view, the specimen is to be regarded as a detached "weathered *section*" that has got "broken" from an individual "*Eozoon*" perpendicularly to its "septa" before it became imbedded. Considering the arrangement and *thinness* of the ribs—"*scarcely two lines in thickness*"—and the comparatively large size of the specimen, "six and a half inches in length, and about four inches broad," there seems much improbability that it could have got detached from a massive "organism," such as "*Eozoon*" is supposed to have been.

Secondly, the "septa are in the state of white carbonate of lime," some "portions" of which exhibit "cleavage planes." "There are also a number of small veins or cracks passing nearly at right angles to the septa, and filled with carbonate of lime, similar in general appearance to the septa themselves;" and the same mineral, in larger examples, occurs in other places, a "white patch" of it having "obliterated the chambers" in one part.

From these statements, and the presence of nothing more than a "doubtful microscopic structure" in some parts of the "fossil," and from the appearances presented by the "admirable photograph" of it, "executed by Mr. Norman,"† we feel ourselves warranted in suggesting that the "septa," "veins," and "white patches," are all of one and the same origin—purely mineral.

Thirdly, the "matrix" of the "fossil" is a "dark-coloured, coarse, laminated limestone, holding sand, scales of mica, and minute grains and fibres of carbonaceous matter." The "septa," it is stated, "present, for the most part, merely traces of structure, consisting of small parts of canals, filled with the dark colouring matter of the limestone."‡ A representation of a "section of one" of the septa is given by Dr.

---

* "Quarterly Journal of Geological Society," No. 91, August, 1867, pp. 253-257.

† The lithograph of the specimen illustrating Dr. Dawson's paper represents the "septa," &c., less imperfectly defined than they are in the photograph; for copies of which we are indebted to Dr. Carpenter.

‡ Dr. Sterry Hunt, the Chemist and Mineralogist of the Canadian Geological Survey, states that the fossil is "penetrated by the blackish *argillaceous limestone* which envelopes it."—"Esquisse Géologique du Canada," p. 7.

Dawson, "showing" the so-called *canals* "imperfectly infiltrated with black (carbonaceous?) matter." Looking at Dr. Dawson's figure Pl. XII., fig. 1), and his description, we shall be much deceived if the "canals," such as they are delineated, be anything else than aggregations of the "minute *grains* and *fibres* of carbonaceous matter" belonging to the "matrix" that have got entangled in the carbonate of lime while crystallizing out in the presumed "septa," as is often seen in minerals vitiated or rendered impure by foreign admixtures.

Other objections might be urged—such as the fact of the so-called "chambers" being filled with the same "dark stone," or mechanically formed deposit, as the matrix—the implied admission that the "minute veins of calcareous spar traversing the septa, and the cleavage planes, which have been developed in some portions of the latter," are "crystallized structures," that might "mislead any ordinary skilful microscopist;" but the aforementioned are sufficient. Moreover, the "few rare instances only," or "obscure" indications, of the "nummuline layer," spoken of, have, we believe, been as much misunderstood as the same part is in type specimens of "*Eozoon Canadense.*"

Closing for the present our remarks on the Tudor "fossil," we may briefly suggest that it is nothing more than the result of infiltration of carbonate of lime, which has penetrated into a parting between two layers of the laminated arenaceous limestone; or it may be an example of anastomosing strings of segregated calcite; in short, *it may be anything consistent with the nature of its matrix, or the conditions under which the latter has existed.*

Dr. Dawson has made an objection to our use of the term "eozoonal." We are not aware of having gone beyond what has or would have been done by others; indeed, it could easily be shown that we are actually behind Dr. Dawson himself in this respect. We described as "eozoonal" certain ophites from Connemara, Donegal, India, Bavaria, the State of Delaware, and the Isle of Skye; and *no valid reasons have been offered to show that we were wrong*, or even that we have strained the meaning of the term.

It is somewhat singular that Gümbel, who has used the term in a less restricted sense than we have (*but who believes in "Eozoon"*) has escaped all adverse criticism. He is perfectly correct; for, in assuming "the presence of Eozoon in the crystalline limestones of Finland," from the fact of their containing "rounded, cylindrical, or tuberculated grains of pargasite"—and that the "coccolite-bearing limestone of New York seems to be closely related" to them, and to the "Eozoon ophicalcite of Steinhag"—he is only carrying out the "received doctrine" to its proper extent.

"Eozoonal" rocks, we are certain, will turn out to be much more common than may be conveniently admitted. Of late, specimens of various kinds of ophite have fallen under our notice. We have obtained examples, according to their labels, from "Egypt," "Neibiggen," "Italy," and "Scandinavia;" and, although differing more or

less from the Canadian rock, they could not be separated from it, as regards their general characters.*

Supported by so many examples, as well as those described in our former Paper, we shall be much deceived if all ophites do not contain some feature or other of the genus "Eozoon;" and as such rocks are common, and belong to *crystalline masses of all geological ages*, believers in this "organism" may felicitate themselves on the prospect of establishing lots of new species, or "varieties."

Regardless of the complete evidence that we adduced, proving the Connemara ophite to be essentially "eozoonal," Dr. Carpenter has lately decided, even contrary to his previous identifications, that "the evidence of its organic origin rests on its partial analogy to the eozoonal rock of Canada. It is, therefore, upon the character of the serpentine limestone of *Canada*, not upon the nature of the Connemara marble, that the question of organic origin entirely turns."†

This is precisely one of the terms to which we intend to adhere in discussing the question. While examining the various structures of "*Eozoon Canadense*," we shall test them as displayed in one of two specimens obligingly presented to us by Dr. Carpenter himself: at the same time we purpose giving additional illustrations from extra-Canadian specimens when necessary.

2. *Foraminiferal Considerations.*

It is stated that "*Eozoon Canadense*" consists of "chamber casts" in serpentine or other minerals, connected by narrow neck-like divisions or "stolons"—invested with an "asbestiform" or a "nummuline cell wall"—and enclosed in a calcareous "intermediate skeleton," penetrated by a number of dendritic and other forms representing the "canal system." The object of our previous Paper was to show that these several features are merely mineral products.

It is now admitted, but not until after the publication of our view, that in "highly crystalline rocks" (of which "eozoonal" ophite is undoubtedly an example), "organic remains may be simulated by mere mineral appearances" (Dawson)—that the features of the presumed organism can be "separately paralleled elsewhere" (Carpenter), i. e., in others besides ophitic rocks: we, however, it is alleged, have, "through defective observation, failed to distinguish between organic and crystalline forms."‡

---

* We have also seen specimens in the Jardin des Plantes and the *Exposition Universelle*, which, on proper examination, we have little doubt will prove to belong to the same category. We observed in the former Institution a specimen, marked "8 N, 2965" (the name of its locality could not be made out): another beside it, from Corsica; and two, "2931," from Tuscany. The Prussian section of the Exhibition, Class 40·20, contained an acervuline specimen, numbered "850."

† "Proceedings of the Royal Society," vol. xv., p. 506.

‡ "Quarterly Journal of Geological Society," vol. xxiii., p. 261.

In the following sub-sections, we purpose treating of the different "eozoonal" features. Although it would appear that our former "attempt" has failed to bring over to our side those who originated the "received doctrine," we, nevertheless, feel perfectly satisfied of its complete fallacy; and we trust to establish the view we have taken of it to the perfect satisfaction of every thoughtful inquirer.

a. "*Cell Wall.*"—We propose to consider this part very closely, because declaredly by it "the organic origin of *Eozoon* is capable of being most unmistakeably recognised" (Carpenter). Moreover, it affords a "notable illustration" of our "defective observation" (Dawson); also, of our "errors of fact so remarkable, that they can only be accounted for on the belief that when" our "Paper was written," we "knew it only by decalcified specimens, and had never seen it in thin transparent sections; for" we "describe it as composed of parallel fibres of chrysotile packed together without any intermediate substance" (Carpenter).

The allegation of "defective observation" may be left to be judged of by the sequel. As to the above statement respecting the "proper wall," it does not appear to have been made after a very satisfactory perusal of our Paper; for, although we described this feature in the terms stated by Dr. Carpenter, we also mentioned that it is "often seen with the fibres standing apart." Further, not only is there given a representation of this particular feature in Fig. 1 of our Plate XLI.; but we have actually advanced a hypothetical explanation of it.* Nay, it may be put forward as a remarkable fact, that, at the time our Paper was read, we were the first who unequivocally described the "nummuline layer" as containing any separated aciculi at all.†

Whatever doubt attaches to their former descriptions of the "nummuline layer," there can be none pertaining to the terms in which Drs. Dawson and Carpenter now describe it. Both speak of it as essentially a calcareous cell wall penetrated by separated threads of serpentine. Taking such a restricted view, this part, then, cannot in any instance, as we have stated it to be, be composed of "parallel fibres packed together without any intermediate substance," or, according to Dr. Carpenter, of aciculi "standing side by side like the fibres of asbestos."

Now, considering the abundance of cases to be seen in Canadian "eozoonal" ophite strictly agreeing with our description, we cannot

---

* "Quarterly Journal of Geological Society," vol. xxiii., pp. 191, 193, 195, and 199.

† Respecting Dr. Carpenter's "belief" that when our "paper was written" we "knew this layer only by decalcified specimens, and had never seen it in thin transparent sections," we can assure him that it is quite erroneous. We only referred to one of the kind ("Quarterly Journal of Geological Society," vol. xxii., p. 193, Pl. XIV., fig. 3); more being unnecessary, because, in our opinion, such sections afford but a very ***imperfect, and in many cases an erroneous idea*** of the nature of the "nummuline layer." Decalcified specimens are by far the most instructive and most trustworthy, as will be seen hereafter. We could similarly dispose of some other like statements, somewhat personal, made by Dr Carpenter; but our Paper must be devoted to purely relevant matter.

but feel surprised at the tenacity with which the more restricted view is held. But to show whether it is our opponents, or ourselves, who labour under "defective observation," we have given a representation of a portion of the "nummuline layer" in Plate XLI., Fig. 1, taken from one of Dr. Carpenter's sections, magnified 120 diameters, which we have decalcified.*

At *d* is represented a portion of the "nummuline layer," in this instance, consisting of distinctly separated aciculi. The separations were filled up with carbonate of lime or calcite, now dissolved out. At *c*, is another portion with the aciculi in perfect contact. At *b*, the aciculi or fibres, as they must now be called, present a somewhat modified aspect, being neither "glistening white," nor "cylindrical," as in the previous places; but having the usual colour of serpentine, and the structure of chrysotile or asbestos. At *a*, the last modification is in an incipient state; the fibres, in this case in the serpentine, being represented by mere incised lines, individually more or less interrupted in their continuity, and varying in their distance from one another.

We have next to draw attention to another example in the same section (more or less paralleled by many others in it), which equally proves that the above four varieties of the "nummuline layer" are no more than modifications of one type.

In Figure 2, the letter A denotes a wide opening, formerly filled with calcite or the "intermediate skeleton," lying between two portions of serpentine constituting "chamber casts." The low side, at *d*, of the opening presents the aciculi beautifully developed (which is also the case at the upper side, at *d*), standing out from the surface of the serpentine, and distinctly separated. Following the aciculi upwards and to the left, they gradually become less distant from one another; and finally pass into the compact state at *c*, where it is impossible to observe the smallest openings between them, each being defined by nothing more than its own bounding surfaces, exactly as are the fibres of asbestos.† On the opposite side, the aciculi are for the most part standing apart.

Viewing the separated aciculi by themselves, they may be considered to closely resemble the "minute projections" or casts of pseudopodial tubuli which Dr. Carpenter has noticed on the siliceous "chamber casts" of specimens of *Amphistegina*, dredged by Professor Jukes off the coast of Australia: but to believe that the two cases are *identical*, when in the former the aciculi are plainly seen to graduate into a state which completely excludes the possibility of their being casts of *wall-enclosed* tubuli, the imagination requires to have more play than can be allowed in a matter-of-fact discussion.

---

* The section from which the figure has been taken did not, when it came into our hands, exhibit with sufficient clearness the different "eozoonal features," though *quite as well as any other* "thin transparent sections;" so we were induced to decalcify it.

† The fibres, *c*, erroneously appear in the figure as if slightly separated.

More remains to be noticed in this example. In our former Paper we contended that the "nummuline layer" is not a calcareous "proper wall" *independent* of the "chamber casts," but merely their external serpentine changed into its asbestiform condition of chrysotile; and we gave an illustration, "selected out of a number of the same kind," which "*demonstrated*" the *truth of our view* :* this case *has been totally ignored.* It is singular that Dr. Carpenter's section is quite prolific of precisely similar cases. The one under notice, which is equally demonstrative, shows the edge of the serpentine, at *a*, distinctly cut with lines, frequently corresponding in their distances from one another with the diameter of the adjoining separated aciculi, into the bounding surfaces of which, in point of fact, they run. The same phenomenon is displayed at the upper portion of the opening, where the divisional lines are only just appearing. With such modifications as those lettered *a*, *b*, *c*, and *d* (and many more that we are prepared to bring forward), *the assertion is inexplicable to us that the "cell wall in no instance presents the appearance of chrysotile, or of any other fibrous mineral*, when examined with care under sufficiently high powers"† (Dawson).

In order to explain, on the "eozoonal" view, the various appearances presented by the "nummuline layer," it might be suggested, as in another case, that the compactness of the aciculi is the result of "metamorphic changes" to which these parts have been subjected; thereby causing them to lose their typical character. Thus, in the case under Figures 1, and 2, *d* (Pl. XLI.), it is conceivable that, as the *siliceous* aciculi ("casts of pseudopodial tubules") are contained in a calcareous matrix, the substance of the latter may have been removed by percolating waters containing carbonic acid; thus allowing the aciculi free to enlarge, through intumescence, and become juxtaposed.‡ But this explanation totally fails to account for the asbestiform condition of the "cell wall:" for, by no possible means, *or by no sound process of reasoning*, can it be supposed that the separated aciculi could be converted into the imperfectly developed divisional structure of the modification, lettered *a*, which is indisputably incipient chrysotile. From the one extreme, of separated aciculi, to the other, of imperfectly chrysotilized serpentine, there is an unbroken passage—an insensible gradation—*demonstrating* the "nummuline layer" to be of purely mineral origin. This conclusion is equally proved by the perfectly corresponding changes that occur in veins of chrysotile, as shown in our former Paper, and to be further elucidated in the present one.§

---

* "Quarterly Journal of Geological Society," vol. xxii., Pl. XIV., fig. 2.

† "Quarterly Journal of Geological Society," vol. xxiii., p. 262.

‡ Vermiculite, related to loganite and serpentine, swells out on the application of heat; so do other hydrated minerals, as the zeolites; also the fibres of chrysotile on exposure to air (Delesse).

§ The hypothetical explanation of the presence of carbonate of lime between the aciculi, advanced in our previous Paper, will be supplemented by additional evidences given in the section on the "Mineralogical Considerations."

Dr. Carpenter regards the "structure of the nummuline chamber wall" to be a "feature," by which "the organic origin of Eozoon is capable of being most unmistakeably recognised;" and accordingly he has been led "confidently to assert that no parallel to it can be shown in an undoubted mineral product."* This is a *strange assertion* to be made after we had stated that, in numerous instances, grains of chondrodite, imbedded in calcite, as in a specimen from New Jersey, are "more or less encrusted with an asbestiform layer, which exhibits modifications, speaking advisedly, the exact parallel of those common to the proper wall" of "*Eozoon Canadense*:"† it is *equally strange* that both Drs. Carpenter and Dawson have *ignored* this specimen. We could describe another, one of the kind that has been detected by us in the coccolite marble of Tyree; but this "parallel" has already been pointed out by Dr. Gümbel, who discovered it in a specimen of a somewhat similar rock occurring at New York.‡ He has, moreover, determined that the grains of "green hornblende (pargasite)," characteristic of crystalline limestone, at Pargas, in Finland, are similarly invested. In the latter instance, "a careful microscopic examination of the surface of the grains" revealed numerous small aciculi, called "small tubuli," consisting of a white substance, and otherwise resembling those belonging to the "nummuline layer" of "*Eozoon*."§

In our early examination of the part under consideration a difficulty, which we mentioned, occurred to us.‖ Observing that the "sarcode chambers" of the different superimposed layers are furnished with both an *upper* and an *under* "proper wall"—and that "the successive layers, each having its own proper wall, are often superposed one upon another without the intervention of any *supplemental* or *intermediate* skeleton" (Carpenter)—it struck us that, on the "eozoonal" view, the pseudopods, presumed to have penetrated the *under* "proper wall," could not extend themselves, as their egress would have been effectually barred by the *upper one* of the immediately subjacent layer of chambers. Dr. Carpenter, who has noticed our objection, appears to have misunderstood it; as the "fact" he has adduced against us, and which he assumes we had "no acquaintance with," is not to the purpose:¶ nevertheless, the "fact that many foraminifera (both recent and fossil), having perforated shells, habitually grow affixed to sea weeds, corals, shells, &c., and that the attached side possesses the characteristic tubular structure no less than the free," is of considerable importance, viewed in connexion with his belief, "that there intervenes in the living state a thin layer of sarcode between the shell and the subjacent surface." Assuming this to be the case—and our

---

* "Quarterly Journal of Geological Society," vol. xxii., p. 221.
† Ibid., vol. xxii., pp. 196, 197, Pl. XIV., figs. 5, 6.
‡ "Canadian Naturalist," December, 1866, p. 99.
§ Ibid., December, 1866, p. 98.
‖ "Quarterly Journal of Geological Society," vol. xxii., p. 191.
¶ "Quarterly Journal of Geological Society," vol. xxii, foot note, p. 225.

own observations are in favour of it—the circumstance will go far to sustain our "objection;" inasmuch as there is required in "*Eozoon*" a vacancy to hold a "layer of sarcode;" whereas, in the cases to which we referred (and we are acquainted with a number of others), there exists no representative of the kind, either in the form of a "siliceous layer," or anything else; the space between two "chamber casts," that rest one upon the other, being crossed by and filled up with *continuous* aciculi.* We did not, when adducing this point, regard it in a stronger light than a difficulty: it was not urged as a positive argument on our side; but we now do so; and, at the same time, we *challenge its subversion.*

Reflecting on all the evidences and arguments given in this and our former Paper in connexion with the "proper wall," *we feel certain that* the original description *we gave of it is the only published one that can be said to be correct; and we are thoroughly convinced that our view of its nature is incontrovertible.* It is a feature composed of *juxtaposed* as well as *separated* aciculi: it is part and parcel of the "chamber casts," being mineralogically an allomorph of their component serpentine: added to which, the "fact" last brought forward shows clearly *that no unquestionable evidence* can be adduced in favour of the belief, that the "nummuline layer" is the representative of the pseudopodial or tubulated cell wall of a foraminifer; for, as such, it would in numberless cases have been functionally useless.†

b. "*Intermediate Skeleton.*"—We have nothing of importance to add to our former remarks on this part; nor, from the absence of any evidence or argument against us, is anything more required to sustain the view we hold of its being identical with the matrix containing grains of pargasite, &c., in various crystalline rocks.

c. "*Chamber Casts.*"—Referring to what is stated in our former Paper respecting the isolated grains of coccolite and other minerals in Tyree marble, also those of chondrodite in the crystalline limestone of New Jersey, being strictly analogous to the "chamber casts of Eozoon," Dr. Dawson commences one of his arguments by stating, that "if all specimens of *Eozoon* were of the acervuline character, the comparisons of the chamber casts with" such grains "might have some plausibility. But it is to be observed that the laminated arrangement is the typical one.‡

On what ground does Dr. Dawson make the last statement? The same question equally applies to a similar one made by Dr. Carpenter. A character to be "typical" must be general; but the "laminated arrangement," although often beautifully developed in specimens from

---

* "Popular Science Review," vol. iv, Pl. XV., Fig. 10 (Carpenter, and Rupert Jones).

† It must not be overlooked that the "elongated bundles" with "*tangentially*" arranged fibres, to which Dr. Carpenter has "seen no parallel in other Foraminifera," equally show the impossibility of the "nummuline layer" being an organic production.

‡ "Quarterly Journal of Geological Society," vol. xxiii., p. 263. Dr. Gümbel, like ourselves, has identified the grains of coccolite and pargasite, respectively occurring in the crystalline limestones of New Jersey and Finland, with the "chamber casts." Why is our case no more than a *plausible comparison*?

some localities in Canada, is not *general* even there (" The acervuline portions make up a large part of the Canadian specimens of Eozoon," Sterry Hunt*); and it is extremely rare in other countries. We have met with only a few specimens from Connemara offering an approach to it; while all those we have examined, collected on the Continent, have the "chamber casts," with an acervuline arrangement: besides, the specimens described by Dr. Gümbel "show throughout this irregular structure, which seems to characterize the Bavarian specimens;"† and those collected at Krumau in Bohemia, by Professor Hochstetter, are essentially acervuline. In describing any organism having a wide geographical range, no naturalist would consider that plan of growth which marked it *in only one locality* (or which may be only beautifully exhibited in a few museum or cabinet specimens, selected out of a large number in a different condition on account of possessing such feature) *to be general or "typical."* Rather, would he consider it to be exceptional.‡

One of the many interesting points connected with "eozoonal" ophite is, that the granules or "chamber casts" may consist of different species or varieties of mineral silicates, serpentine and diopside (or malacolite) being common. In one place a specimen may have the layers of granules formed entirely of the former, and in another of the latter. "Some sections exhibit these two minerals filling adjacent cells, or even portions of the same cell, a clear line of division being visible between them" (Hunt). In one of the sections presented to us by Dr. Carpenter there occurs a layer of granules, apparently consisting of chondrodite, lying between others of serpentine. Loganite is another mineral which often replaces the latter. Connemara ophite occasionally displays precisely the same differences. In a specimen before us, a layer, composed of granules of serpentine, lies immediately adjacent to another, formed of an aggregation of crystals of what appears to be malacolite intermingled with calcite. Another specimen consists of parallel layers, varying from a quarter to an inch in thickness, of granular serpentine, (?) pyrallolite, openly cleaved malacolite, and a guttate wax-like mineral (? deweylite). Calcite, which is more or less associated with all these minerals, *fills up the cleavage openings* of the malacolite; demonstrating that in the latter the silicate has undergone partial removal, and that the resulting openings have become filled in with a carbonate.

Long ago Dr. M'Culloch directed attention to the different silicates occurring in the green-spotted pink marble of Tyree;§ and his state-

* "Canadian Naturalist," December, 1866, p. 90.

† Ibid.

‡ Dr. Dawson has charged us with the admission that the "laminated forms are essentially Canadian." What is stated in our Paper is—"we had got the impression that in the Grenville varieties the chamber casts were rarely arranged otherwise than in laminæ:" but after examining some specimens presented to us by Sir W. E. Logan, "we saw that the acervuline arrangement was a characteristic feature of the Canadian ophite" ("Quarterly Journal of Geological Society," vol. xxii., p.190).

§ "Western Highlands of Scotland," vol. i., p. 54, &c.

ments respecting the phenomenon are completely confirmed by our own observations. We find a number of grains (spots) consisting of hornblende, others of sahlite, a few of quartz, and some apparently of serpentine; while an occasional one appears, half composed of hornblende, and the other half of sahlite.

Dr. Carpenter has stated that we "do not attempt to offer any feasible explanation of the fact," that the "siliceous mineral" forming the "chamber casts" may be serpentine in one place, pyroxene in another, or loganite in another." Chondrodite and pyrallolite may also be added. Nevertheless, it so happens that we did make the "attempt:" but we fail to find that a single argument, or evidence, has been urged against our "explanation" of its being a pseudomorphic phenomenon. But, whether the attempt has been successful, or not, we hold the "fact" to be demonstrative of the mineral origin of the "chamber casts;" since it is strictly paralleled in the case of the *different* mineral silicates composing the grains imbedded in the Tyree pink marble, and other allied rocks.

Considering that the "chamber casts of *Eozoon Canadense*" have never been found to consist of any other mineral than *a silicate*, and that there is no reason to a palæontologist why they ought not to occur composed of a carbonate, it is singular that the latter point has *been so little noticed by writers opposed to our views.* The use we have *made of the general fact, to their disadvantage, has been totally ignored,* though an *indirect attempt* has been made to invalidate it. Dr. Dawson has *incidentally* stated that the "chambers are filled in different specimens with" (besides the silicates alluded to) "calcareous spar, or even arenaceous limestone."* In mentioning the last substance, evidently the Tudor specimen was thought of; but we decidedly refuse to accept the case as one to the point: and as regards the "calcareous spar," we are unacquainted with any *published instances* of this mineral being an infilling of the kind.

Further remarks on the composition of the "chamber casts" will be made in another place.

d. "*Canal System.*"—We have already stated, as our opinion, that the examples which have been brought forward of this part are nothing more than imbedded crystallizations, resembling arborescent silver, the various kinds of dendrites in agates, branching aragonite, &c. Most of the cases alluded to were brought forward by way of illustrating the "canal system;" and *we have nothing to complain of as to any want of attention* to them on the part of Drs. Dawson and Carpenter; but it is our duty to mention that the *strictly homologous* case of metaxite has been very slightly noticed by the one, and *ignored* by the other. Dr. Dawson, who admits to having "not seen specimens" of this mineral, puts the case aside by simply stating, that "it is evident

---

* "Quarterly Journal of Geological Society," vol. xxiii., p. 263.

from the description and figure given" of our specimen, "that, whether organic or otherwise, it is not similar to the canals of Eozoon Canadense."* Notwithstanding, however, this *denial* of the similarity that we have contended for, it will not much surprise us if Dr. Dawson himself has not *unconsciously* shown, in another way, that we are right; for it is strongly to be suspected that the "siliceous bodies" with "minute vermicular processes projecting from their surfaces," occurring in "Laurentian limestone from Wentworth," are nothing more than forms of metaxite, or some allied mineral,—a suspicion that equally applies to the "tubuli of surprising beauty," detected by Dr. Gümbel "in small isolated compact portions of the carbonate of lime" in "a specimen of crystalline limestone from Boden, in Saxony."†

The irregularity of the "canal system"—the "very remarkable differences in size and form" of its "definite shapes"—is a point not to be overlooked; while it must be remembered that our statement remains uncontradicted that "no such differences characterize the canal system of any known foraminifer, fossil or recent."

Morever, examples of the "canal system" occur where it is impossible to conceive that their matrix had any relation to a "supplementary" or "intermediate skeleton" A specimen of Canadian laminated "eozoonal" ophite, presented to us by Dr. Sterry Hunt, contains an isolated piece of micro-crystalline calcite, about an inch in diameter, which, on being decalcified, exhibited a number of beautifully-developed dendritic forms, opaque and transparent. How are these to be accounted for? It may be suggested that the piece is an aggregation of fragments of the "skeleton": in this case the *forms* ought to be in a *fragmentary* state as well; but their perfectly unbroken condition will not allow the suggestion to be entertained for a moment. It may be thought that this is a case in which the "skeleton" and the "canals" are of abnormal growth: the latter "run wild" enough under ordinary circumstances of occurrence; but here they are inexplicably erratic on the foraminiferal view. And it is infinitely more so with the "tubuli of surprising beauty, both singly and in groups," discovered by Dr. Gümbel in the Boden "*crystalline limestone*," *minus* other "eozoonal" structures.

On the supposition that the rock just named contains the *debris* of "*Eozoon*," and that the so-called "*tubuli*" are of organic origin, the "isolated compact portions of the carbonate of lime" containing them must be regarded as fragments of the "intermediate skeleton;" or—in what way have the "*tubuli*" become imbedded in the "compact portions?" Imagine portions of the "skeleton," with *beautiful* examples of the "canal system," to occur without any vestige of "chambers," or their "cell-wall!"

It is now time to go into the subject of the chemical composition of the "canal system" in the celebrated "Madoc specimen." When first

---

* "Quarterly Journal of Geological Society," vol. xxiii., p. 263.
† "Canadian Naturalist," December, 1866, p. 100.

brought before the notice of geologists by Dr. Dawson, in a letter dated March 28th, 1866,* the case was announced to be an example of "*Eozoon* preserved simply in carbonate of lime, without any serpentine or other foreign mineral;" and a "conclusive answer to" our "objections." Now, what proofs have come to light to warrant this expression? In a "Note on supposed Burrows of Worms in the Laurentian Rocks of Canada," subsequently read (June 20, 1866,) before the Geological Society, nothing more appears with reference to the case than an allusion merely to "fragments of *Eozoon*, not fossilized by serpentine, but simply by carbonate of lime!"† While in the brief and only other account published of it by Dr. Dawson, and written about twelve months after the announcement was made, the infilling is ignored altogether!‡ Dr. Carpenter, it is true, mentions something additional on this point; but he merely makes the statement, unsupported by any proper evidence, "that the canals, being filled with a material either identical with or very similar to that of the substance" ("crystalline dolomite," Dawson) "in which they are excavated, are so transparent as only to be brought into view by careful management of the light."§ Considering that our "elaborate arguments had at one time a strong show of support" (Warrington W. Smith)—is this all that is required to prove that the canals are filled with "carbonate of lime pure and simple?" Must the Madoc specimen, now, be considered "to close the discussion?" Supposing the "transparent material" to be a *carbonate*, which is not at all made clear, it may still be assumed that the "very characteristic examples of the canal system" are of purely mineral origin. The substance in which they are "excavated," according to Dawson, is "crystalline dolomite"—a matrix rarely free from some imbedded crystalline or other configurations. In our former communication we showed that the *dolomitic* rocks of the North of England are often charged with *cylindrical* coralloidal or dendritic shapes, composed of *carbonate of lime*:|| if these were on a small scale, *many of them* would closely resemble the "various forms of the canal system" observed in the "fragment" from Madoc. Most of the limestones occurring in the latter place are siliceous dolomites, and contain more or less carbonate of iron: as such, they are likely to hold configurations of a "transparent material," possibly a ferriferous calcite, or other mineral carbonate, which, without proper testing, might be considered as "either identical with or very similar to, that" of their imbedding substance.

But another case, similarly interpreted, has also turned up. Dr. Carpenter has detected in "sections of a specimen of *Eozoon*" dendritic and other forms of the "canal system," which, as they agree closely in transparency and colour with their enclosing calcite

* "Quarterly Journal of Geological Society," vol. xxii., p. 228.
† "Quarterly Journal of Geological Society," vol. xxii., p. 609.
‡ "Quarterly Journal of Geological Society," vol. xxiii., p. 261.
§ "Quarterly Journal of Geological Society," vol. xxii., p. 212.
|| "Geology of Canada," 1863, pp. 592, 593.

(" intermediate skeleton"), can only be exhibited with Collins' "graduating diaphragm." " Now these parts, when subjected to decalcification, show no trace of canal system ; so that it is obvious, both from their optical, and from their chemical reactions, that the substance filling the canals must have been *carbonate of lime.*"* Another section which Dr. Carpenter has obligingly presented us with is, in some places, crowded with " forms :" some are quite colourless and transparent, and *cannot be seen under full light,* agreeing thus far with the above description. The *colourless* examples have been distinguished by Dr. Carpenter himself, who has drawn a circle in ink around them. One of the circles contains the beautiful case, represented in Figure 11 (Pl. XLIV.) as seen magnified 210 diameters, under Webster's condenser, with graduating diaphragms. The "forms" are enclosed in transparent calcite, affected with both rhombohedral and macrodiagonal cleavage. Now rises an important question :—If these " forms " consist of transparent " carbonate of lime"—why do they, as is invariably the case with them and others in the section, present no traces of the cleavage which so eminently distinguishes the calcite ? Where the " forms" remain covered with, or enclosed in, the calcite, the cleavage lines of this mineral pass over them (as shown at one end of the long cylindrical body in the figure) ; which might mislead some into the idea that the " forms" possess the same crystalline structure as their matrix : but in no instance, where they are uncovered, have we observed the least appearance of any divisional structure in their component substance. From these considerations, it may be well imagined that when we partially decalcified the section—that is, dissolved the calcite down to only a slight depth, so as not to allow the "forms" to drop out—we were not surprised to find them still remaining. Those that are represented in the figure were standing out above the remaining calcite, and as clear as the purest glass.

The account lately given by Dr. Carpenter, and published with the knowledge of our experiment and observations, affords no further light on this question. " The larger branches" of the " canal system," it is now stated, " were infiltrated with serpentine, and the middle branches with sulphide of iron, while the smallest branches were filled with carbonate of lime, of the same nature"—" of the same crystalline character"—" as the matrix."† Is cleavage referred to in the last part of this quotation ?‡ If so, it may belong to the calcite overlying the " canals," as is certainly the case in our specimen.

It has often been mentioned that " canals" have been seen containing a " yellowish-brown coloration," or "black matter"—a circumstance

---

* " Quarterly Journal of Geological Society," vol. xxiii., p. 264.

† " Quarterly Journal of Geological Society," No. 98, May, 1869, pp. 117, 118.

‡ We are glad to gain any additional information from our opponents on the nature of the "branches filled with carbonate of lime," and their enclosing matrix; but nothing of the kind appears in the above and latest published account of them. Dr. Carpenter makes some allusion to the " cleavage planes" we have referred to—in such a way, however, that it could be turned not only against " Eozoon," but against himself.

which has given rise to the belief that "the infiltrating mineral has been dyed by the remains of sarcode still existing in the canals of Eozoon." In one of the sections presented to us by Dr. Carpenter, a few of the "canals" were labelled as containing "carbonaceous matter": they might be said to have a brownish colour—looking at them by transmitted light; but after decalcification, and examined as opaque objects, they presented nothing more than a dull white appearance, somewhat like the ordinary examples. The Tudor specimen has also been described by Dr. Dawson as having the "canal system imperfectly infiltrated with black (carbonaceous ?) matter;" which may be taken as *inorganically* explained by the mineralogist and chemist of the Canadian Geological Survey, Sterry Hunt, who states that the "fossil" is "penetrated" with the same material as its matrix—a "blackish argillaceous limestone."

We have grounds for suspecting that this "carbonaceous" piece of evidence in favour of the organic origin of "*Eozoon*" has been, or is all but abandoned; and we anticipate a similar fate for the "strong odour of musk, to some extent" given out by "some specimens when cut,"* which has lately been adduced as a circumstance of the same tendency.

e "*Stolons.*"—Our former criticisms on the parts now entered upon have brought out the admission from Dr. Carpenter, that his figure of the selected example of "passages of communication between the chambers" of "Eozoon," stated to have their "exact parallel in *Cycloclypeus*,"† is "somewhat diagrammatic."‡ As no further elucidatory remarks of such "passages" have been published, clearly it would be a waste of time on our part to add another word to what we have already brought forward (and which still remains invalidated) in proof of their being nothing more than "flattened or table-shaped crystals of apparently pyrosclerite," wedged in transversely or obliquely between the serpentine granules or "chamber casts."§

3. *Mineralogical Considerations.*

Examining "eozoonal" ophite in the decalcified state, the serpentine will be seen without a flaw in one place, while in another, immediately adjacent, it is cut up by divisional planes extremely irregular, or rudely parallel; presenting a confusedly fractured appearance, or a somewhat platy structure. Whether the serpentine is in scattered granules ("acervuline"), or arranged in layers, these peculiarities manifest themselves indifferently in the centre, and at the surface; but they are common in the latter situation. The platy serpentine frequently becomes more or less fibrous, often passing into that form of the "nummuline layer," which has its fibres "standing side by side

---

* "Quarterly Journal of Geological Society," vol. xxv., p. 118.

† "Quarterly Journal of Geological Society," vol. xxi., p. 62.

‡ Ibid., vol. xxii., p. 225.

§ Ibid., vol. xxii., Plate xiv., figs. 10, 11, p. 208. Plates of white granular serpentine (flocculite) in the same position have doubtless also been taken for stolons.

like asbestos," and which we hold to be typical chrysotile. Furthermore, the fibres, as already pointed out, likewise become gradually or abruptly changed into white glistening *aciculi*, retaining their juxtaposition, or separated from one another by well-marked interspaces—now open, but filled with calcite before decalcification.

The serpentine granules have their surface also often changed into a white flocculent substance,* which may be granular, coarsely platy, fibrous, or acicular: these variations are well seen in Fig. 3 (Pl. XLI.) taken from one of Dr. Carpenter's sections.

The divisional peculiarities, when on the large scale, as in the cases first noticed, cut the serpentine into a variety of forms, with rounded or hollowed surfaces, rudely resembling both acervuline and laminar "chamber casts:" in many cases the resemblance is so striking as at once to suggest the idea that the forms are examples of "chamber casts" in process of formation. When calcite occupies the divisional interspaces, as often happens (or rather *was* the case before decalcification), it may be conceived that such calcareous intercalations are examples of the "intermediate skeleton" in course of elaboration.

Dr. Carpenter's section, the first one brought under notice, affords numerous cases of the above modifications. Over a considerable portion of it may be seen, as represented in Fig. 4 (Pl. XLI.) long parallel divisions (*c*), in some places completely, or imperfectly closed—in others, more or less open: the latter condition is due to the removal of the calcite consequent on decalcification. The closed divisions are partially, or entirely filled up—sometimes with flocculite—generally with a crop of fibres or aciculi, separated and in contact, projecting from their sides. Occasionally the serpentine, forming the sides of these divisions, is incipiently, or completely chrysotilized; and in numerous cases there is the same passage from "asbestiform fibre" to separated aciculi, as seen on the surfaces of "chamber casts."

That these divisions are nothing more than *cracks*, is rendered palpable by all their appearances, especially by their intersecting uninterruptedly the layers of "chamber casts" (*a*), as well as the calcareous intercalations (*b*) forming the so-called "intermediate skeleton."

Reverting to cases of the same kind which occurred to us while engaged with our former Paper: we pointed them out as totally destructive of the opinion that ascribes the "asbestiform layer" to pseudopodial tubulation; and we adduced an example *unmistakeably on our side.*† *How has it been disposed of?* Dr. Carpenter affirms to having met with "numerous examples" of the kind, but "so destitute of the characters of the true asbestiform layer," that he has "no hesitation in regarding" them "as *either* originally a product of *inorganic* agencies, or as the result of metamorphic changes in a structure originally *organic*." *How can such an argument be handled?* If we lay hold of the "inorganic" side, it slides over, and presents the "organic" one!

* Called *flocculite* in our former Paper.

† "Quarterly Journal of Geological Society," vol. xxii., p. 196, Plate xiv., fig. 4.

Returning, for a moment, to the answer already given in a previous section,* as it is equally applicable to the present case; we shall simply reply to the "metamorphic" portion of Dr. Carpenter's argument, by offering an example, selected from a number of the same kind, to be seen in one of the *cracks* (*c* x., in Fig. 4), previously noticed; and which is represented in Fig. 5 (Pl. XLII.) as seen by a power magnifying 210 diameters. The two walls of this crack (C), which intersects a layer of "chamber casts united into a continuous horizontal lamella, are" crowded with both compact (*c*) and separated aciculi (*d*); the latter cylindrical, parallel, and as much "true casts of pseudopodial tubuli" as any that are known to form the "nummuline layer." So we may safely defy every attempt to make the argument, based on this example, present any other than the "*inorganic*" side. Again, how does Dr. Dawson treat the example described and figured in our Paper? The occurrence of "veins of fibrous serpentine or chrysotile," occurring in Canadian ophite, is mentioned; but evidently the cases "which were well known" to Dr. Dawson are not the same; since, "under a high power, they resolve themselves into prismatic crystals in immediate contact with each other;"† whereas the one we brought forward, when similarly magnified, is seen, and it was stated so, to contain *aciculi*, not only in close contact, but *separated !*‡

We have represented in Figure 6 (Pl. XLII.) another example, occurring in Connemara ophite, interesting as throwing further light on the changes characteristic of serpentine. It consists of a vein (*a*) intersecting a considerable mass of this mineral. As in numerous other cases, the serpentine here and there changes in colour, graduating from translucent dark green to a pure opaque white; while in many places it is colourless and transparent. Near one end (upper part of the figure) the vein strikes through a cluster of granules ("chamber casts") of green serpentine, above which it can be traced for a short distance (though too high to be represented), gradually thinning out. In the opposite or downward direction, it intersects a mass of compact serpentine, and terminates in a large cavity (A). In passing through the serpentine, the vein, with a few exceptions, is transversely asbestiform, the fibres being, as in chrysotile, unresolvable or indefinite, in consequence of their complete juxtaposition: in some places the divisional lines are separated; and here and there they are extremely faint: in one part, for a short distance, the vein is scarcely differentiated from the intersected serpentine. Adjacent to the granules the vein becomes acicular; the aciculi being in general closely (*c*) juxtaposed, and in a few places distinctly separated (*a*, *b*). A few of the neighbouring granules have their surface hispid with independent aciculi (*d*), undistinguishable from those belonging to the vein. On entering the cavity, the vein, here asbesti-

* See *ante*, p. 516.
† "Quarterly Journal of Geological Society," vol. xxii., p. 226, foot note.
‡ "Quarterly Journal of Geological Society," vol. xxiii., p. 262.

form, becomes divided (*c*, *d*); in one division (*d*) the compacted fibres change into aciculi, distinctly separated.

Similar asbestiform veins, more or less parallel to the last, occur on each side of it: indeed, the specimen, a slab a few inches in length, is in one part intersected by a number of the same kind of veins, dividing it into thick sub-parallel plates, which by further subdivision would become converted into layers of "chamber casts." Other important changes, to which serpentine is subject, remain to be noticed.

Dr. Carpenter's section, examined by transmitted light before it was decalcified, showed very distinctly a number of striking examples of the "canal system;" but still no proper idea could be formed as to their origin and nature. Decalcified, and examined as opaque objects, however, an important light was thrown upon them.

Like other specimens, noticed in our former Paper, the one now under examination occasionally shows the passages that had been occupied with the calcareous matter of the "intermediate skeleton" clogged with flocculite; and this substance occurring as "white amorphous masses." Fig. 7 (Pl. XLIII.), represents a passage, unusually wide, containing one of these "masses" of considerable size, which is broken up (A, B), and divided into thickish plates—straight, curved, or wavy—lying close and parallel to one another, or opening out and again conjoining repeatedly, or variously diverging.* The plates themselves also break up into a great variety of slender configurations, that are filamentous, foliaceous, arborescent, palmate, or rod-like; and elliptical, circular, or crescentic in their transverse section: in short, there seems to be no limit to the variety of "shapes" assumed by the plates of flocculite. This substance varies also in texture, being spongy, granular, or compact; in the last state resembling dense snow, from which condition it occasionally passes into one resembling imperfectly translucent ice; or it assumes the character of serpentine, having precisely the green colour, varying in shade and translucency, of this mineral.

The various forms presented by the flocculite in this section, especially the arborescent, are certainly beautiful; and when a number of the different kinds are clustered together in the same field of view, a more pleasing sight cannot be revealed by the microscope.

Our former investigations made us acquainted with examples, leading us to adopt the conclusion (previously arrived at by Dr. Carpenter) that the "amorphous masses" and "definite shapes" are no more than "*modifications of one type*;" but we had no idea of meeting with a specimen so completely demonstrative of this view. We now go further. In Dr. Carpenter's section, the edge of the serpentine, contiguous to the example of the "canal system" represented in Fig. 7, B x, is seen

* It is a source of much regret that we find ourselves unable to give any more than a rude sketch of one (simple compared with many) of the numerous examples which the section displays; but we have taken every pains to represent its leading points as truthfully as possible.

to be both gradually and abruptly changing into flocculite, cylindrical rods, and aciculi. Hence, it is impossible to resist the more comprehensive conclusion that, in this case, the "canal system," "chamber casts," and "nummuline layer," are all structural modifications of serpentine.

We may digress to bring forward another case strongly tending in the same direction. Decalcified specimens, before us, of an ophite, beautifully "eozoonal,"* have the chamber casts" consisting, as usual, of green serpentine, which, however, frequently changes colour, becoming here opaque white, and there colourless and translucent. The serpentine is in some places, as represented in Fig. 8 (Pl. XLIII.), affected with two dissimilar sets of cleavage, one lamellar, and the other somewhat fibrous, intersecting each other obliquely (*a*, *b*.) Occasionally this phenomenon first shows itself by the set, *a*, alone, and next by the gradual introduction of the other or fibrous set, *b*. Where both sets are fully developed, the cleavage partings are each often wide, which causes the "chamber casts," now opaque and white, or translucent, to appear as if broken up into long slender rhomboidal prisms.† Next, the cleavage solids become more and more separated from one another, their edges at the same time getting more and more rounded off; so that, at last, they appear as clusters of cylindrical rods (*c*), undistinguishable from the "brush-like" examples of the "canal system."‡

Clearer evidence of the conversion of the serpentine into the "definite shapes," forming the "canal system," cannot be required; and it corresponds remarkably with the one furnished by Dr. Carpenter's section; the only difference being that in the latter the rods are generally milk-white and opaque; while in the Neibiggen specimen they are nearly colourless and translucent. This is the character generally of the "canal system" in the latter specimen, whether it is represented by *simple* or *dendritic forms*.

---

* We got a small slab of this ophite (which, as far as can be made out, is labelled Neibiggen), in London, in the summer before last. The locality appears to be in Germany.

† The third cleavage set, intersecting both the other sets, necessary to form a *complete* solid, was not observed; but from the peculiar obliquity of the prisms, and the dissimilarity of the sets that are exhibited, we are disposed to regard these prisms as triclinic (Fig. 8*x* represents a transverse section of one of the prisms): in this case, serpentine may belong to the trebly oblique system. Dr. Carpenter's section also shows the serpentine, in some places, broken up by two dissimilar sets of cleavage, obliquely intersecting each other; but the resulting prisms are often not so regular as those occurring in the Neibiggen ophite: it is also noteworthy that the cracks which cut through the adjacent layers of serpentine and calcite ("chamber casts" and "intermediate skeleton") in Dr. Carpenter's section correspond in direction with the least developed set; while the layers themselves run more or less parallel with the other, or better developed set. This coincidence is curious; and it is suggestive of the possibility that there is some relation between the *rude* and the *regular* divisional structure of serpentine, and the *acervuline* and the *laminar* arrangement of the "chamber cast of Eozoon" respectively.

‡ In the figure, only the tops of the rods are represented, as seen when looking down upon them.

It must next be borne in mind that the cleavage partings above noticed had an infilling of carbonate of lime before they were decalcified. A precisely similar case, it will be recollected, we pointed out in a specimen of ophite from Connemara.* How will a mineralogist explain this phenomenon? The cleavage partings in the serpentine of the one case, and in the malacolite of the other, he knows full well were originally closed; and in that state each parting had its two walls in perfect contact. There is no other explanation open to him than that the substance of these mineral silicates has been abstracted from the cleavage divisions, and replaced by calcareous matter. In the Neibiggen specimen, the partings are observed to be gradually getting wider: at first they were divisional lines of the finest character; next, slightly open separations; afterwards, well-marked chinks or wide fissures; finally, indefinite irregular passages. It would be unphilosophical to assume that the process of abstraction stopped at the last stage.

The cases lately brought forward have an important bearing on a question discussed in our former Paper, and which has already been briefly alluded to in the present one: we refer to the presence of carbonate of lime between the aciculi of the "proper wall," where they are separated. No doubt whatever rests on our mind that the presence of this substance in the cleavage partings of the Neibiggen and other specimens, also in the acicular interspaces of the nummuline layer, is due to one and the same cause; but how it got into these openings is a point on which we can still offer no more than a hypothetical explanation.

Our hypothesis is based on pseudomorphism, as understood by mineralogists. Blum, who has laboured most assiduously at this department of science, separates the phenomena, embraced by it, into two classes—one comprising "alteration pseudomorphs," and the other, "replacement pseudomorphs."† The first class includes examples of minerals in which certain of their essential chemical constituents have been removed, and replaced by others, as in cuprite (CuO) converted into malachite (CuO, CO_2+HO), leucite into oligoclase, &c. The *second class* includes those minerals in which all their original constituents, being completely eliminated, have been replaced by others, as chlorite after magnetite, chalcedony after fluor, cassiterite after orthoclase, hematite after calcite, &c., &c.‡

Reverting to the *acicular layer*, and assuming it to consist of a hydro-magnesian silicate, there can be no doubt that in the cases on which we are engaged the aciculi are separated by carbonate of lime.

---

* See *ante*, p. 519.

† Pseudomorphic phenomena have been investigated, with more or less success, by a number of mineralogists and chemists. Other divisions have been proposed; but we adopt the one given by Blum as being the simplest for our purpose.

‡ The Mineralogical collection in the British Museum contains several very interesting specimens of pseudomorphs, which we have been allowed to examine by Professor Maskeyline, and his assistant, Mr. Davis.

And considering that the layer is immediately adjacent to the so-called "intermediate skeleton," composed of carbonate of lime, there is not much difficulty in understanding that this substance might, in numerous instances, infiltrate itself into the thin inter-acicular separations.

But the cases with which we are at present especially concerned do not admit of so simple an explanation; as we have to account for the presence, not of thin films of carbonate of lime, but of much thicker intercalated portions of this substance, equalling the diameter of one, two, or more aciculi. Guided by the changes undergone by the serpentine and malacolite in the Neibiggen, Connemara, and other specimens, we are strongly inclined to refer the present cases to Blum's class of "replacement pseudomorphs."

The mineral serpentine, although belonging to a group of difficultly reducible silicates, is rendered, when in the condition of chrysotile, or flocculite, comparatively easy of decomposition under proper conditions. Besides, considering the difference between these allomorphs, one being fibrous, and the other granular,—that they are often intermixed,—and that the asbestiform variety is not structurally uniform, being incipiently fibrous here, and perfectly fibrous there,—it must be admitted, that not only do the divisional structures referred to afford facilities for pseudomorphic action, but they are eminently favourable to the development of that "infinite variety of detail," as noticed by Dr. Carpenter, presented by the separated and juxtaposed aciculi of the "nummuline layer" seen in decalcified specimens. From what is known of the numerous examples of *replacement* pseudomorphs, described by Blum, Bischof, Breithaupt, Delesse, Müller, and others, there is no difficulty in assuming that the crowded and infinitesimally small fibres forming this "layer," also the loosely aggregated particles composing the granular flocculite — both kinds composed of a hydro-magnesian silicate, the most soluble of its class—might be replaced by calcite or dolomite, if the rock containing them were furnished with carbonate of lime (as is the case with ophite), and had been subject at any time to deep-seated hydrothermal action : or, a similar change is admissible, supposing serpentine alone to be present, and allowing the rock to have been permeated by heated water, holding a calcareous carbonate in solution. The silicate composing the fibres or aciculi might in the latter case be substituted by calcite, or dolomite.

Such is our hypothesis, modifications non-essential to its principle being allowed, to account for the origin of the calcite, where it separates the fibres of the "nummuline layer." We also offer it to explain how the "definite shapes" have been formed out of plates, prisms, and other solids of serpentine, viz., by the erosion, or incompleted waste, of the latter, and the replacement of the removed substance by calcite,—the "definite shapes" being the residual portions of the solids that have not completely disappeared. And we hold, in accordance with this view, that the calcite or replacing carbonate, enclosing the residual portions, and which forms the "intermediate skeleton," is like-

wise nothing more than a pseudomorph after serpentine.* In short, we see no reason to conclude otherwise than that the whole of the "eozoonal" structures have originated through chemical substitutions.

We have next to adduce a case, which, apart from its bearing on the origin of "eozoonal" structures, is of the utmost importance in elucidating the phenomena manifested by pseudomorphosed minerals, and rock masses. The veins, in the cases already figured, exemplify the change of compact or amorphous serpentine into fibrous chrysotile, and the replacement of the latter variety by ordinary calcite; but in the present one (Fig. 9, Pl. XLIV.), the replacement has taken place unaccompanied by any structural change. Before decalcification, the vein under notice, which intersects some massive serpentine in one of our slabs of Connemara ophite, seemed to be wholly filled with chrysotile; but, after being subjected to the action of dilute acid, we found the infilling had in a great measure disappeared; only portions of it, both compact (*c*) and separated (*d*), were left adhering here and there to the walls of the vacant space, now a fissure; while at the bottom (*f*), where decalcification had not proceeded deep enough, there still remained the infilling in a completely fibrous state. But we now observed, what had not been particularly noticed in our first examination, that the vein, which is slightly coloured, varied in shade, the portion answering to what had been dissolved out being the lightest; it therefore became evident to us that the fibrous infilling consisted of two substances,—one an insoluble silicate, and the other a soluble carbonate. This case, like others that have been brought forward, can only be explained by pseudomorphic action—a hydro-magnesian silicate replaced by what we believe to be

---

* To us this hypothesis, if even suggested to account for the formation of the irregular beds of crystalline limestone interposed among the metamorphic rocks of Ireland and Scotland, has more in its favour than the one promulgated by Sterry Hunt to explain the origin of the far greater calcareous masses belonging to the Laurentian system of Canada. The existence of the latter rocks seems to have materially influenced Sir Charles Lyell, Professor Ramsay, and others, in accepting the "received doctrine." A gigantic foraminifer, such as "*Eozoon Canadense*" is reputed to have been, would have just the sort of skeleton to produce reefs of limestone. But, unfortunately for this argument, Sterry Hunt has most emphatically pronounced "the often-repeated assertion that organic life has built up all the great limestone formations" to be "*based on a fallacy*:" they "owe" their "origin to *chemical reactions*, which are still going on in the ocean's waters, and which have in past times given rise *directly* to limestone strata; in which the occurrence of shells, corals, and *Eozoon*, is *only accidental*." ("Geology of Canada, 1866," p. 201; "Quarterly Journal of Geological Society," vol. xxi., p. 70).

[In connexion with this subject, we find the following statement by Professor Hull:—"The researches of Sir William Logan and his colleague of the Geological Survey of Canada, followed by other naturalists, have demonstrated that even the oldest known limestones on the surface of the globe owe their origin to Eozoon" ("Quarterly Journal of Science," July, 1869). We much regret that this statement is open to adverse criticism. It will be pronounced to be "based on a fallacy" by Dr. Sterry Hunt; and the point gratuitously assumed to be "demonstrated" by the Director of the Irish Geological Survey is damaging to his own belief in "Eozoon;" inasmuch as it necessitates the disproving of our position, that the limestones referred to (we mean the non-serpentinous) are remarkable for the *total absence of any reliable evidences* of "eozoonal" remains.—April 20, 1870.]

carbonate of lime. The distinctive peculiarity of this case, however, is that the latter substance, which is structurally satin-spar, retains the fibrous character of the chrysotile.

Finally, pseudomorphism, in crystallized examples, leaves intact the form of the crystals. It will be well to bear this point in mind, as cases may exist in which the "definite shapes" retain their forms, and yet consist of a substance different from what is common to the "canal system." It will be time enough, however, to discuss such possible cases when they are known to us; but, so far, we see no reason why the "definite shapes" may not occasionally become more or less carbonated (as siliceous minerals often are), or be composed of a soluble silicate, without losing their form; and consequently in a condition to yield as readily even to dilute acid as their matrix ("intermediate skeleton"), especially if it consist of dolomite.* We, therefore, think that the Madoc case, and others of the kind, presumed to "close the discussion" against us, have been immaturely considered, and do not at all justify the conclusion they have given rise to.

Dr. Carpenter has asserted that we "do not attempt to offer any feasible explanation of the fundamental fact of the regular alternation of lamellæ of calcareous and siliceous minerals."† We have not avoided this point; nor do we conceal our inability to explain it satisfactorily. But, if Dr. Carpenter wishes to construe our inability into evidence in his favour, he is assuredly mistaken; for a similar "alternation" is not uncommon as a purely inorganic phenomenon. We have already pointed out the interlamination of calcareous and siliceous minerals in pargasitic and other rocks;‡ and we now adduce a similar case, mentioned by Dr. Gümbel, occurring in the gneiss of Wunsiedel, in the Fichtelgebirge, where "specimens" of this rock "exhibit sheets of hornblende of from five to fifteen millimeters, separated by limestone layers of from fifteen to twenty millimeters in thickness."§ Such examples strongly confirm us in our belief that the "fundamental fact," however it may have been produced, is no more than a peculiar mineral arrangement—most probably a superinduced phenomenon.||

Dr. Carpenter declares, that he is "prepared to maintain the organic origin of Eozoon on the broad basis of cumulative evidence afforded by the *combination*, in every single mass, of an assemblage of features which can only be *separately* paralleled elsewhere; and in the repetition of this

---

* A small piece of elæolite, and another of "intermediate skeleton," composed of dolomite (which, it must be remembered, is difficultly soluble compared with calcite), were placed in weak acid, such as we usually employ in "eozoonal" decalcifications: both were dissolved.

† "Proceedings of the Royal Society," vol. xv., p. 506.

‡ "Quarterly Journal of Geological Society," vol. xxii., p. 210.

§ "Canadian Naturalist," December, 1866, p. 95.

|| Alternating layers of brown limestone and dolomite, ***perpendicular*** to the beds containing them, are common in a Permian rock near Sunderland, in Durham: they might be taken for laminæ of deposition (see "Quarterly Journal of Geological Society," vol. xxii., p. 212.

combination with the most wonderful exactness, over areas of immense extent."* This passage contains a remarkable admission, which in point of fact is next to surrendering the organic origin of "Eozoon;" for the features of this "fossil," it is conceded, "can be separately paralleled by mere mineral arrangement.† So, there is little now left in favour of the "received doctrine" but the "broad basis of cumulative evidence" above referred to; which consists of the "combination" of "chamber casts," "intermediate skeleton," "nummuline layer," and "canal system." Has a "combination" of all these "features" been discovered "in every single mass" of Canadian "eozoonal" ophite? Even taking the expression in a much more limited sense than its construction bears—how does it happen that the "proper wall" is generally absent, or so very imperfectly preserved, in "masses" of this rock from Grenville and the Grand Calumet? And why is it that neither the "proper wall," nor the "canal system," occurs in "masses" at Burgess? Where, "over areas of immense extent," has a "repetition of this combination" been found? The researches of Dr. Gümbel and Professor Hochstetter have certainly not supplied Dr. Carpenter with evidences bearing out his assertion. Again—are "eozoonal features" only "separately paralleled" in pargasitic and other crystalline limestones, in which both the "chamber casts" and "intermediate skeleton" occur? Or—is such the case in chondroditic rock, which possesses not only the "features" just named, but also the "nummuline layer?" Nay—have not the "canal system" and "nummuline layer" (and of course the "intermediate skeleton") been "distinctly observed" by Dr. Gümbel "around scapolite nodules, encrusted with serpentine, associated with calcareous marble at Steinhag, in Bavaria?"‡

This "combination" argument is based on an exceptional fact; for the "assemblage" referred to by Dr. Carpenter is rarely seen in other varieties of ophite than the one occurring at Petite Nation; but, whether exceptional or not, it requires some further notice.

We feel persuaded that the fact, as just admitted, represents a phenomenon inherent in serpentinous rocks, arising from their mineral composition, and the physical conditions under which they may have existed—a phenomenon to which Breithaupt's term, paragenesis, might not be inappropriately applied.

We have in previous pages made known that serpentine is often seen intersected or broken up by divisional planes—some regular and parallel, others exceedingly irregular. From a number of evidences we have met with, and which have already been noticed in detail, we have

* Quarterly Journal of Geol. Soc., vol. xxii., p. 223.

† The concession, however, was only made *after* we had pointed out the parallel cases. Neither Drs. Dawson, Carpenter, nor Sterry Hunt, in their original memoirs, refers to the "intermediate skeleton," and the "chamber casts," being "paralleled" in the Tyree and other marbles,—the "nummuline layer," by modified chrysotile, filling up true fissures,—and the "canal system," by dendritic configurations of metaxite, &c.

‡ This case will be further noticed presently.

assumed that when heated solutions containing calcareous matter, or carbonates, penetrate the fissures, the adjoining serpentine will become converted from a silicate into a carbonate; and hence will be formed isolated or variously connected grains, lumps, and layers of serpentine ("chamber casts"); while the separations are occupied by intercalations of calcite, or dolomite ("intermediate skeleton"). Here and there the surfaces of the grains, &c., will become concurrently platy, floccular, or asbestiform: in the latter state the serpentine is converted into its allomorph, chrysotile, in the form of an investing layer; which through further changes will become acicular, with the aciculi often removed, and their places occupied by calcite, &c. ("nummuline layer"). The calcareous intercalations between the granules, &c., will retain more or less residual serpentine, which, if remaining chemically unchanged, will become converted into white amorphous masses, parallel lamellæ, solid bunches of rounded filaments, cylindrical and broadly flattened rods—simple and branching ("canal system"), characteristic of another allomorph, metaxite. As serpentine rocks are liable to all, or to only a few of the above changes, depending on the various conditions under which they may have existed, we do not apprehend any material objections to the principle (there may be to minor points) of our hypothesis from those who have paid attention to the subject; we, consequently, have the strongest confidence in the conclusion that "the combination of an assemblage" of "*eozoonal features,*" *in the rare instances in which* it occurs, is inseparable from ophite—that it is an inevitable and a purely correlative phenomenon. The "eozoonal" rock of Petite Nation certainly stands out prominently as a case in point: but the circumstance is due to no more than a concurrent development of the various forms assumable by its protean mineral, serpentine, under favourable conditions; and it is no less paragenetic than is assuredly the case with the "combination" occurring in chondroditic and pargasitic crystalline limestones.

It ought not to be expected that the phenomenon can be met with except in rocks approaching mineralogically to ophite. There are not many. Of the few that are known, we have shown them to present a "combination" so strictly "eozoonal," and so conclusively demonstrating the paragenesis of their ophitic types, as to leave nothing more of the kind to be desired.

Dr. Gümbel has made known a very curious fact, which has some relevancy to the subject we are discussing. At Steinhag, in Bavaria, there occurs "*Eozoon*" associated with the *never-failing metamorphic* limestones, schists, and gneiss. The limestones "often contain small lenticular masses or nodules, consisting chiefly of scapolite, crystalline and almost compact, measuring fifty by twenty millimeters, and even much more, around which serpentine is arranged in a concentric manner;" and "in the parts around these nodules" there were "sometimes distinctly observed tubuli, canals, and even indications of a shell-like structure." Dr. Gümbel "could not satisfy" himself, "after numerous examinations of fragments of such masses, whether" he "had to

deal with the commencing growth of an *Eozoon,* or merely with a concretionary mass; since the granular structure of the scapolite centre could never be clearly made out. Moreover, the arrangement of these nodules, arranged in a stratified manner, is opposed to the notion that they are nuclei of Eozoon."* Now, here is a case (and Dr. Gümbel failed, evidently much against his inclinations, in determining it to be organic) which indisputably furnishes a "combination," manifesting the mineral origin of the "creature of the dawn" so plainly that this "organism" must be altogether repudiated by every palæontologist; for obviously the case is a beautiful example of pseudomorphism and allomorphism combined,—of scapolite changing into serpentine, and the latter assuming the form of chrysotile (the "shell-like structure"),—while the "tubuli" and "canals" are probably metaxite, or some allied mineral, originating directly from the serpentine, or the scapolite.

It is stated by Dr. Gümbel as being "well known that the crystalline minerals, which in numerous localities are found in the metamorphic limestones of Bavaria, often present rounded surfaces, as if they had at one time been in a liquid state. As examples of these, Naumann mentions apatite, chondrodite, hornblende, pyroxene, and garnet. The edges and angles of these are often rounded; the planes curved or peculiarly wrinkled, and only rarely presenting crystalline faces; having, in short, a half-fused aspect, and offering a condition of things hitherto unexplained. One of the best known instances of this is found in the green hornblende (pargasite), from Pargas in Finland."† Dr. Sterry Hunt has lately drawn attention to the same superficial features, occurring in certain minerals from the calcareous *veins* intersecting the Laurentian rocks of Canada.‡ When preparing our former Paper, we were forcibly struck with the resemblance of the outside of the grains in the Pargas and Tyree marble to the rounded and pitted surfaces, characterizing the *acervuline* "chamber casts" in "eozoonal" ophites.

Dr. Sterry Hunt, repudiating the idea put forward by some writers that the phenomenon, as seen in *veins,* is "due to a commencement of fusion," regards it "as the result of a partial resolution of previously formed crystals." The opinion published antecedently by ourselves as to the origin of the flocculent coat often seen on the granules of serpentine in "eozoonal" rocks is substantially the same; for we have ascribed the presence of this covering, as well as the "nummuline layer," to the gradual waste or decomposition of the serpentine by deep-seated hydrothermal action; and we are disposed to think that the distinguished chemist of the Geological Survey of Canada will yet see reasons for agreeing with us by extending this idea to explain the origin of the irregular surfaces of the so-called "chamber casts" occurring in "eozoonal" rocks, as well as those of the crystalline minerals found in the metamorphic limestones of Bavaria and other countries.

* "Canadian Naturalist," December, 1866, p. 90.

† "Canadian Naturalist," December, 1866, pp. 97, 98.

‡ "Canadian Naturalist," December, 1866, p. 124; "Geology of Canada," 1866, p. 190.

Dr. Sterry Hunt, however, has endeavoured to make out for this phenomenon a genetic distinction, depending on its occurrence in *veins*, or in *beds:* in the former, the minerals, according to his view, lost their angles by a dissolving agent; in the latter, their irregular form is original, being the impression of the inner wall of the "cavities" or "sarcode chambers of *Eozoon*." There may be a "marked contrast" between the superficial aspect of the *vein*-minerals, and that of the same species disseminated in *beds;* but the "contrast" seems rather to be due to the different conditions under which their respective calcareous gangues, as they are constituted at present, were produced. The crystalline character of the *vein-gangue*, it may be admitted, was a direct depositional result; while that of the *bed-gangue*, as will be conceded by most geologists, has been developed by metamorphic action : other and consecutive agencies would not, on this view, be inoperative. So far as we are enabled to judge from passages in the "Geology of Canada" for "1863" and "1866," we are strongly inclined to the belief that the *grains* or granules of serpentine, loganite, coccolite, apatite, quartz, &c., occurring in *veins*, do not possess sufficiently distinctive characters to warrant their differentiation, as regards origin, from similar forms of the same minerals found in *beds;* and if it should prove correct that the "rounded crystals" of the one, and the "chamber casts" of the other, are identical, the circumstance will certainly be fatal to "Eozoon."*

That "heated watery solutions" have "permeated" both *beds* and *veins*, and that these solutions have transferred various mineral constituents from the former to the latter, is quite our opinion, as it is Sterry Hunt's.† But does not such a process involve a powerful argument against the doctrine of the organic origin of "*Eozoon ?*"—for what more likely source is there for the precited *vein-minerals* than the *bed-minerals* of the same species that present the so-called "semi-fused aspect?"

4. *Chemical Considerations.*

In one of his passages, referring to ourselves, Dr. Carpenter makes a statement that requires some notice in the present place. "While asserting that by no conceivable process could the animal substance originally occupying the tubuli of the nummuline layer have been replaced by siliceous minerals, they have entirely ignored the fact, stated by me, that this very replacement has taken place in recent specimens in my possession."‡ It is difficult for us to understand how

* We feel much regret at having no specimens of the minerals in the granular state, mentioned in the text, from the calcareous *veins* intersecting the Laurentian rocks of Canada: it would, therefore, be conferring a marked favour on us, if any one would send to our address, Queen's College, Galway, a collection of them, as well as the same kinds from the associated *beds* of crystalline limestone.

† "Geological Survey of Canada," 1866, p. 193.

‡ "Proceedings of the Royal Society," vol. xv., p. 507.

such a statement has been made; for we have neither "asserted" the one, nor "ignored" the other.*

It was stated in our former Paper that we must "be excused accepting any explanation of the process of infiltration, unless it accounted for the present appearances of all the presumed sarcode-encasements;" and we especially referred to those cases in which the "*parallel lamellæ* disposed like the leaves of a book," the "*rounded filaments*" of the "solid bundles,"† and the *fibres* of the asbestiform layer, are not separated by any parietal divisions. Dr. Carpenter virtually admitted the difficulty which attaches to this point by proposing a process that has more of alchymy than chemistry in it, and discarding the simple one originally suggested by Dr. Dawson. By either *ordinary* chemical, or mechanical infiltration, the tubuli of an *undisputed* "nummuline layer," or "canal system," would become filled up with mineral matter, producing "perfect models" of "pseudopodial threads," and other sarcodic extensions. Dr. Carpenter, however, seeing the "compact" and "solid" nature of the cases to which reference has been made, and knowing well that the extensions just alluded to often unite and form "coalesced bundles in recent foraminifers," emphatically declares that "each case represents a mere aggregation of the elementary forms of sarcodic prolongation,"—that "they are not *imitations*, *but the very threads or prolongations themselves* turned into stone by Nature's cunning, by a process of *chemical substitution* which took place, particle by particle, between the sarcode body of the animal and certain constituents of the ocean-waters *before* the destruction of the former by ordinary decomposition."‡

Our view of such a "process" (it was against the "conceivability" of *it* we argued) is correctly represented by Dr. Carpenter in the following passage:—"This idea has been designated by Professors King and Rowney as so completely destitute of the characters of a scientific hypothesis as to be wholly unworthy of consideration."§ We are, therefore, not surprised that Dr. Carpenter has been under the necessity of abandoning it.‖ But we do not think that his position has been much

* See "Quarterly Journal of Geological Society," vol. xxii., p. 195.

† These two are varieties, according to Dr. Carpenter, of the "Canal System." Dr. Dawson, it would appear, does not recognise the organic origin of them, particularly the "white amorphous masses" into which they pass (see "Quarterly Journal of Geological Society," vol. xxiii., p. 262). But not a particle of evidence—merely an expression of belief—is offered by way of invalidating the proofs which so completely identify them genetically with the typical representatives of the "canal system."

‡ "Intellectual Observer," vol. vii., p. 290, &c.

§ "Quarterly Journal of Geological Society," vol. xxii., p. 220, *foot note.* The "*quasi-alchymical*" idea which we have opposed is given in the "Intellectual Observer," and the "Proceedings of the Royal Society of London:" see our former Paper, in "Quarterly Journal of Geological Society" vol. xxii., pp. 202, 203.

‖ See precited *foot note.* It is singular, however, that Dr. Carpenter makes no admission of his having abandoned this "idea;" *nor is there any allusion to the circumstance in any of his Papers on "Eozoon" published since we exposed it.* But apparently

improved by adopting the hypothesis proposed by Professor Milne Edwards to explain the "infiltration of bones and teeth by a process of substitution *during* the decomposition of their animal contents;" because, although it may be correct in this case, the hypothesis, applied to "*Eozoon Canadense*," requires the "sarcodic prolongations" to remain distended, elongated, or expanded *after* death—conditions which it is impossible to conceive, considering that such parts in foraminifers "consist of the softest and most transitory form of living substance" (Carpenter).

Up to the present time the "replacement" minerals (serpentine, loganite, diopside, chondrodite, &c.) of "*Eozoon*" have chiefly been found in metamorphic rocks and veins, but never in ordinary unaltered deposits. Nevertheless, Dr. Sterry Hunt has broached the "novel theory" that they have been "*directly deposited* from the seas of the time," as "chemical precipitates, which have filled by a process of infiltration its chambers and canals."

"In support of this view," the following evidences have been brought forward:—1st. The deposition of silicates of lime and magnesia from natural waters; 2nd. "The great beds of sepiolite in the unaltered Tertiary strata of Europe;" 3rd. "The contemporaneous formation of neolite;" 4th. "Glauconite, which occurs not only in Secondary, Tertiary and recent deposits, but also in Lower Silurian Strata."*

First. In the "Geology of Canada," 1863, p. 559, it is stated that the "water from Gillan's Spring, in Fitzroy, which had been evaporated to one-tenth and filtered, became turbid by further boiling, and gave a flocculent precipitate, which consisted of silica combined with lime and magnesia. A similar reaction was observed with the Varennes and other saline waters; and likewise with the waters of the St. Lawrence and Ottawa rivers." Obviously the analogy of these examples (which were *only obtained at a high temperature*) to the Laurentian "precipitates," we are engaged with, is a very questionable and remote one.

Second. "A hydrous ter-silicate of magnesia, which has been described by the name of sepiolite, occurs associated with limestones and clays of Tertiary age, and of fresh water origin, in France, Spain, Morocco, Greece, and Turkey. It is the meerschaum of some

---

there is some difficulty that prevents his ridding himself of it; for he as much as suggests that the "double asbestiform layer," which we brought forward (see our former Paper, Pl. xiv., fig. 1, p. 194), may have been formed by the spreading out of coalesced bundles of the pseudopodia that have emerged from the chamber wall, just as obtains with the sarcodic layer of recent foraminifers ("Quarterly Journal of Geological Society," vol. xxii., p. 222). Now, as both layers are more or less "compact and indefinitely fibrous," they, of "course, are not *imitations*" (casts), but the coalesced pseudopods "themselves turned into stone by Nature's cunning *before* their destruction by ordinary decomposition!" Respecting this "double asbestiform layer, we have detected more of the kind in Dr. Carpenter's section; and all of them are only explainable on our view, as elsewhere published.

* "Quarterly Journal of Geological Society," vol. xxi., pp. 67, 70, &c.

authors, and the magnesite of others."* Although no doubt can be entertained that a deposit of the kind referred to does occur, as stated, no one is warranted in assuming that it is in its original condition. There are strong grounds for believing, as is the case with the gypseous and dolomitic beds associated with it, that the *mixed* deposit under consideration was originally differently constituted. Much uncertainty generally prevails among geologists as to the origin of magnesian limestones, which equally applies to the rocks composed of hydro-magnesian silicates: the sepiolite of France and Spain is a case in point. According to Dr. Sullivan and Prof. J. P. O'Reilly,† there occurs extensively in the basin of the Tagus and Duero a white or greyish-white dolomitic limestone, "containing from 25 to 40 per cent. of hydrated silica;" and in parts of the same region, especially at Vallecas, near Madrid, there also occurs a "hydrated silicate of magnesia, $2MgO$, $3\ SiO^2+2HO$, accompanied by halb-opal, a variety of silica, chalcedony, and hornstone in a marl bed." The facts stated "suggest a connexion between these minerals and the siliceous dolomite;" and the "connexion is made more probable by the occurrence of fossils of *Helix,* which, with many species of fresh water shells, are abundant in the lacustrine limestone of the central plateau, converted into meerschaum" (sepiolite). "Another fact which favours it is the occurrence of pseudomorphs of meerschaum after calcite" (or more probably dolomite, as suspected by the authors) "in druses of the former." Sullivan and O'Reilly explain the origin of the sepiolite from the siliceous dolomite by the action on the latter of water holding carbonic acid in solution: assuming this, the whole of the lime would be gradually removed, while the magnesia, slowly combining with the silica, would be converted into sepiolite; and any excess of silica would be converted into halb-opal.‡

The resemblance between the lacustrine deposits of Spain and those of France is so strong in many respects as to lead Professors Sullivan and O'Reilly to suggest a common origin for both. Agreeing with them, we refuse to accept the *second* evidence as a case in point.

Third. The mineral, neolite, which is deposited in some mines in Arendahl, may be received as showing that an alumino-magnesian

---

* "Geology of Canada, 1863," p. 577.

† "Atlantis," vol. iv., p. 315, and "Notes on Spanish Geology," p. 171, 1863.

‡ The ex-President of the Geological Society, Mr. Warrington W. Smyth, in stating "there can be no doubt that the 'Vallecas meerschaum' has been produced by silica, probably hydrated, brought into contact with carbonate of lime and magnesia, held in solution in water by carbonic acid" (see Anniversary Address, "Quarterly Journal of Geological Society," vol. xxiii., p. xvi.), has been misled into giving countenance to Sterry Hunt's view by the "well-known" laboratory fact, noticed by Dr. Sullivan and Professor O'Reilly, as showing the reaction between these bodies. In omitting, which we believe to be altogether an inadvertency, the mode these authors have suggested for the origin of the Vallecas sepiolite—that is, from an already-formed dolomite—the pseudomorphic view they have put forward has been altogether lost sight of; and a totally different one—inapplicable to the case except as an illustration, and involving a *contemporaneous precipitation from a chemical solution*—put in its place!

silicate is generated, and held in solution in subterranean waters ; but, owing to the probability of the solution being formed under pressure and at an elevated temperature, the case cannot be considered as having any relation to the presumed precipitation of serpentine.

Fourth. Glauconite is essentially a hydrous silicate of protoxide of iron and potash, with variable proportions of alumina and carbonate of lime — a composition that consigns this partly chemical and partly mechanical product to the same category as the preceding non-analogical cases. A similar fate assuredly awaits the long-known infilling substance (silica, ferruginous clay, or silicate of iron—with or without lime) of fossilized foraminifers.* The casts of the *Amphistegina*, &c., so often referred to by Dr. Carpenter, are the result—some of mechanical, and others of chemical infiltration ; so that in either case, their origin is no more than that of the commonest fossils. Foraminiferal shells in Cretaceous rocks have often been mechanically filled with chalk-mud.

These are all the evidences that have been adduced to justify the assumption that serpentine, pyroxene, loganite, &c., have been "*directly* deposited as chemical precipitates from the seas in which *Eozoon* was growing, or had only recently perished ;" and that these silicates "penetrated its chambers, pores, and canals, precisely as carbonate of lime might have done."† Is it not significant that a complete collapse has

---

* Mantell and Henry Deane in "Philosophical Transactions," 1846, p. 466 ; Ehrenberg in "Berlin Monatsbericht," Feb., 1855 ; Bailey in "Proceedings of Boston Society Nat. Hist.," vol. v., p. 364, 1856 ; &c.

† "Quarterly Journal of Geological Society," vol. xxi., p. 70 ; and "Canadian Naturalist," December, 1866, p. 125.

Entertaining this "novel theory," Dr. Sterry Hunt consistently ascribes the formation of ophitic rocks to the *direct* deposition of their mineral substances,—the calcite to the precipitation of carbonate of lime, and the serpentine to the precipitation of silicate of magnesia. As regards the latter mineral, this theory is altogether different from that maintained by Bischof, Rose, Breithaupt, and others, who regard it as being invariably a pseudomorphic product—a view to which we have fully committed ourselves (see "Quarterly Journal of Geological Society," vol. xxii., p. 216). Most ophites appear to have resulted, through regional chemical alteration, from hornblendic and augitic rocks; and, notwithstanding Sterry Hunt's arguments and evidences, which we have shown to be untenable, it so happens that he himself has adduced facts strongly sustaining the view to which he is opposed. "Large masses of white granular pyroxene are frequent in beds of limestone in the Canadian Laurentians, generally associated with serpentine, which often incrusts it ; and small nuclei of this pyroxene frequently form the centre of concretionary masses of serpentine :" the latter "may vary from a few inches to a foot or more in diameter" ("Geology of Canada," 1866, p. 205, 207). It is also mentioned that "*crystals* of considerable size—some imperfectly defined, and an inch in diameter—of serpentine, occur imbedded in calcite, in North Burgess" (*Op. cit.*, p. 204) : these "crystals" may be considered as nothing but pseudomorphs. His loganite, a serpentinous mineral, is considered by Dana to be an "altered hornblende" ("System of Mineralogy," 5th ed., p. 221, &c.). For our part, we are strongly disposed to believe that most of the minerals in the Laurentian limestones are due—some directly, and others indirectly—to the pseudomorphism of doleritic, dioritic, and other rocks.

happened to the efforts of both Drs. Sterry Hunt and Carpenter to explain a "process" which cannot but be regarded as "of primary importance in the main question under discussion?"

5. *Geological Considerations.*

It will seem strange to many, after reading the statement in our former Paper of several specimens of Connemara ophite having passed under our notice, possessing the characteristic "eozoonal" features more or less combined, and as perfectly preserved as in Canadian examples, that this rock should be referred to, as having only "a partial analogy to that of Canada" (Carpenter), and as being a "disputed case" (Dawson). If necessary, we could fill a Plate with examples, from our locality, of the "asbestiform layer," arborescent and other "definite shapes," not surpassed by any that have been figured, from Petite Nation or elsewhere, in their seeming resemblance to the "cell-wall" and "canal system" of a nummuline foraminifer, and associated with "acervuline chamber casts," exactly as in "*Eozoon Canadense*." Indeed, the Connemara ophite, with such examples, is more typically "eozoonal" than the *accepted* variety from Bavaria, if the latter contain no better marked "foraminiferal features" than have been detected in it by Dr. Gümbel.

In our former communication, referring to the Isle of Skye ophite, which is *indisputably Liassic in age,* we stated that "no doubt can be entertained as to its eozoonal" character—a statement which may be considered to be sufficiently borne out by our describing it as containing "'chamber casts' occasionally invested with the 'proper wall,'" and "thickish dendritic aggregations:" the latter, it might be understood, we considered to represent "the canal system."* Yet Dr. Dawson sets aside our statement respecting these features by asserting that this rock "is admitted" (by whom?) "to fail in essential points of structure"! It has thus become absolutely necessary for us to give a representation of the "eozoonal" characters of the Isle of Skye ophite, which we have done in Fig. 10 (Pl. XLIV.), magnified 210 diameters, taken from a portion of a decalcified specimen. The "chamber casts" (A, A x), it will be seen, are furnished with an "asbestiform layer" (*d*), as much a "true cell wall" as any examples occuring in the Canadian rock; and consisting of separated and juxtaposed aciculi—parallel and divergent. Owing to the specimen having been ground down to produce a level surface, most of the "chamber casts" have been cut across, which causes the "nummuline layer" investing them to appear as if "bordered with a delicate white glistening fringe;" but below the plane of this surface there are two "chamber casts" (A x), which, when properly focussed, are seen to have their entire surfaces completely "hispid" with aciculi, forcibly reminding one of the recent siliceous casts of *Amphistegina* described by Dr. Carpenter.

---

* "Quarterly Journal of Geological Society," vol. xxii., p. 204.

It would be a marvel to find a Liassic ophite possessing characters strictly identical with those typical of "*Eozoon Canadense*;" still the similarity is surprisingly close. If anything is to be "admitted," it is that the rock, as far as we have ascertained, "fails" in having the "canal system" so remarkably arborescent as it is in the much older ophites. Nevertheless, this feature is well represented by the "thickish dendritic aggregations," also by some other forms we have lately detected strictly identical with the "small" and *common* variety represented by Dr. Carpenter in his original memoir."* The "nummuline layer," too, is a strictly identical "essential point;" but, owing to the "chamber casts" consisting of a very pale green serpentine, in some cases translucent and nearly colourless, the aciculi do not present that striking contrast to the former so beautifully displayed in typical examples.†

One of the arguments we advanced against the organic origin of "*Eozoon*" was based on the fact that this "fossil," although occurring in various geological systems, had not been found except in metamorphic rocks. The way the Tudor specimen (also the "mere fragments" already noticed) was ushered into public notice was calculated to induce the belief that it had been discovered in an ordinary unaltered calcareous deposit. Thus,—"a remarkable specimen of *Eozoon Canadense* has lately been found in Laurentian limestone" ("homogeneous"), "establishing the conclusion previously arrived at from the study of remains of Eozoon included in serpentinous rocks" (Carpenter). Other accounts, however, describe the matrix as a "dark-coloured, laminated limestone, holding sand, scales of mica, and minute grains and fibres of carbonaceous matter" (Dawson),—a "blackish argillaceous limestone" ("calcaire argileux et noirâtre," Sterry Hunt),—a "micaceous limestone or calc schist" (Logan and Vennor),—a rock "comparatively unaltered" (Logan)—"not so much altered as those near Grenville" (Smyth). Thus, after all, the Tudor specimen—whatever its matrix may turn out to be—occurred in a metamorphic deposit; it being from a "region in which the Laurentian rocks of Canada appear to be less highly metamorphosed than is usual" (Dawson).‡ We hold

---

* "Quarterly Journal of Geological Society," vol. xxi., Pl. VIII., fig. 5.

† We have not yet succeeded in obtaining specimens of "eozoonal" ophite from *undoubtedly* later geological periods than the Liassic; but from what we perceive in specimens of serpentine rock, *without any lime*, considered to be Miocene, from Italy, and kindly presented to us by the Chevalier Jervis of Turin, also others, containing lime, some stated to be Italian, for which we are indebted to the firms of Edmondson & Co., and Sibthorpe & Son, of Dublin, and those already noticed exposed in the Paris Exhibition and the Jardin des Plantes, we entertain a strong suspicion that the Tertiary "ophicalcite" of that country will prove to be "eozoonal." A specimen of ophite from "Egypt" in our possession, also possibly Tertiary, contains grains and lumps of serpentine, imbedded in calcite: the latter mineral is crowded with very long parallel aciculi, both separated and juxtaposed.

‡ The *mineral* origin of the Tudor specimen is in no way invalidated by the fact of its matrix being "comparatively unaltered;" as it is not a rare circumstance for slightly

it, therefore, to be still a fact that no vestige of "*Eozoon*" has yet been found except in metamorphic rocks, whether completely changed, or "comparatively unaltered." So far, then, a disastrous failure has attended all the efforts that have been made to meet our implied challenge to believers in "Eozoon"—to produce a single specimen from the "miles in thickness" of "*unaltered* calcareous, argillaceous, and mixed deposits," anterior in age to, or synchronous with, the *Liassic* "eozoonal" ophite of the Isle of Skye.

Nothing daunted by their inability to meet our challenge, our opponents still indulge in a style of reasoning and writing that ill becomes scientific men. Dr. Carpenter has now so much confidence in the "creature of the dawn" as to "believe" that it has lived through *all geological time;* forgetting that by this expansion of faith the mountain he has to remove is correspondingly enlarged. To find no remains of "*Eozoon*" in ordinary *unaltered* rocks, ranging from the Laurentian to the Liassic inclusive, seemed sufficient to shake the faith of the most enthusiastic: it was surely damaging enough to be struggling impotently against a Liassic rock in the state of *white crystalline serpentinous marble* containing "*Eozoon;*" which, "as it recedes from" the agent of this condition, "darkens in colour, loses its metamorphic aspect, and gradually passes into ordinary limestone;"* and becoming in the latter state divested of all traces of the reputed organism! Now, however, Dr. Carpenter has made himself responsible for its occurrence in more recent deposits: he has thoughtlessly allowed himself to be crushed by the *well-examined* chalk rocks, *essentially foraminiferal*, but demonstratively *non-*"eozoonal!"

Faith, there are too many reasons for knowing, frequently waxes beyond all comprehension. We are now unable to resist referring to some remarks by Dr. Carpenter in connexion with the "transparent gelatinous substance," "somewhat similar to the plasmodia of botanists," discovered in deep-sea mud by Professor Huxley, who has named it "*Bathybius*." Although unable to "call it either plant or animal," the latter considers it "a living substance, susceptible of apparently indefinite growth."† Dr. Carpenter describes this *lowest of the lowest* as a "living organism of a type even lower, because less definite than that of Sponges and Rhizopods;" adding, that "the discovery of this indefinite plasmodium, covering a wide area of the existing sea-bottom, should afford a remarkable confirmation, to such (at least) as still think confirmation necessary, of the doctrine of the organic origin of the serpentine-limestone of the Laurentian formation. For if *Bathybius*, like the testaceous Rhizopods, could form for itself a shelly envelope,

altered rocks to contain crystalline aggregations of felspar, and the minerals forming ophites and diabases (see "Geology of Canada," 1863, p. 606; and *Esquisse Géologique du Canada*, p. 20). Rocks of the kind occurring in Connemara contain layers of epidote, &c.

* Geikie in "Quarterly Journal of Geological Society," vol. xiv., p. 19.

† "Quarterly Journal of Microscopical Science," October, 1868; "Quarterly Journal of Geological Society," vol. xxv., p. 118.

that envelope would closely resemble *Eozoon.** Further, as Professor Huxley has proved the existence of *Bathybius* through a great range not merely of *depth* but of temperature, I cannot but think it probable that it has existed continuously in the deep seas of all geological epochs. And so far, therefore, from considering that the discovery of *Eozoonal rock* in the Liassic, or even in *Tertiary strata*, would (as asserted† by Professors King and Rowney in a Paper recently presented to the Geological Society) be a *conclusive disproof* of its organic origin, I am fully prepared to believe that *Eozoon*, as well as *Bathybius*, may have maintained its existence through the whole duration of geological time, from its first appearance to the present epoch; and should be not in the least surprised at bringing it up from 1000 or 2000 fathoms, if I should be enabled to dredge at those depths."‡ The loose logic, inexcusable misstatements, and unbounded faith, characteristic of this extract, fully prepare us for the announcement, after the projected dredging expedition in the North Atlantic is over, that its author is enabled to place before the Royal Society "eozoonal" embodiments of the "spirits" he may bring up "from the vasty deep."

6. *Conclusion.*

Looking merely at the granules and segmented plates of serpentine in "eozoonal ophite," their interposed calcite, and the arborescent forms enclosed in the latter, Dr. Dawson was to some extent justified in believing that collectively these "features" represent a fossil foraminifer; looking at the "asbestiform layer" in its "true" or "typical" state, here and there investing the granules and plates, Dr. Carpenter's belief, that it formed the "proper wall" of the foraminifer, was in some respects plausible. But this is all we can admit. Up to the points mentioned, Drs. Dawson and Carpenter laboured assiduously, and with considerable success. Instead, however, of proceeding farther, *they abruptly closed their investigations*, as if the question were a purely foraminiferal one. They tested their "creature of the

---

* Compare the description of *Bathybius*, over leaf, with this statement: also consider that Dr. Carpenter has diagnosed "*Eozoon*" with structural characters which would entitle it to be placed in the nummuline or *highest* group of the testaceous Rhizopods; while Ernst Häckel would place *Bathybius*, if he believes in it, in his group *Monera*, which comprises "organisms occupying not only the simplest, but the simplest conceivable position of living matter." See "Quar. Jour. of Mic. Soc.," vol. ix.

† This statement does not agree with our *assertion*, which referred solely to *metamorphic rocks* of different geological periods.

‡ "Proceedings of Royal Society," No. 107, p. 191, December 17, 1868. As some of our readers may desire to have further information respecting the foraminiferal mud occurring at great depths, we beg to refer them to some Papers by one of us in "Nautical Magazine,'" 1862; and "Fraser's Magazine," October, 1863, "On Certain Physical and Natural History Phenomena of the Atlantic." It need scarcely be mentioned that mud of the kind brought up from the bottom of the Atlantic, off the west coast of Ireland, at depths varying from 1000 to 1750 fathoms, does not contain a particle of "eozoonal" structures.

dawn" with no independent testimony; contenting themselves, with a few trifling exceptions, by examining it from a *single point of view; even forgetting, in their excusable enthusiasm, to notice certain grave difficulties* they cannot but have observed, and which, *notwithstanding our having pointed them out*, have been left unexplained, and still remain *an insurmountable obstacle* to the *thoughtful* acceptance of the "received doctrine."

Dr. Carpenter proclaims the "moral certainty" of "a number of separate and independent facts" having a "consistency." The facts referred to may be "consistent," but certainly they cannot be called "independent." To us they are strictly and simply correlative. "Independent facts," in the question at issue, must be gathered from those sciences which bear directly upon it—as chemistry, mineralogy, and geology.

Viewing "Eozoon" in its *chemical* relations, it is inexplicable—so much so, that to account for certain persistent characters of the "canal system," and "nummuline layer," Dr. Carpenter has proposed two "ideas," one of which is *altogether unscientific, and the other is inadmissible;* while Dr. Sterry Hunt's hypothesis for the infilling of the "chambers" and "other cavities" has no tangible evidence in its favour. Examined *mineralogically*, it is absolutely necessary to ignore not only a group of well-attested cases, offering a "combination of phenomena" more or less agreeing with those urged in favour of "*Eozoon,*" but equally the clear inference that such "combination" in "eozoonal" ophite is as much paragenetic as it is in chondroditic and other rocks. Regarded *geologically*, "*Eozoon*" signally fails in the circumstances of occurrence, necessitated by the plainest considerations pertaining to sedimentary lithology; never presenting itself except in metamorphic rocks belonging to widely separated systemal periods, and thereby equally failing to meet the most obvious requirements of palæontology.

Finally, to subscribe to the organic origin of "*Eozoon,*" the *chemist* must become a believer in *quasi*-alchymy, and in *direct* oceanic precipitations unknown in nature. The *mineralogist* must assume certain obscure and insufficiently tested bodies to consist of calcite: he must be inappreciative of the various allomorphs of serpentine, and of pseudomorphic phenomena; and consider every imbedded crystalline body—"tuberculated," or "segmented"—"cylindrically shaped," or with angles rounded off—to be the remains of an organism. The *palæontologist*, besides slighting all he knows of the circumstances of petrifaction, must accept as a "fossil" a production never found in rocks that ought to contain it. Even the *zoologist* must believe to be a "*nummuline* foraminifer" what is structurally an *Impossibilitas Naturæ*, in having a "canal system" and "skeleton" that often "*ran wild*" without either "chambers" or a "cell wall;" and in being seldom otherwise than *inconceivably* the result of pseudopodial tubulation.

"Solvite tantis animum monstris,
Solvite, Superi!"

Supplementary Note.

[Read 28th February, 1870.]

Within the last fortnight we have been successful in finding "eozoonal" structures under conditions which unmistakeably establish their origin.

We have first to notice a specimen of ordinary metamorphic micro-crystalline limestone, from Aker, in Sweden. It contains numerous light green grains of pyroxene of the variety known as coccolite, a considerable portion of a colourless translucent variety of a related mineral seemingly malacolite, and a few small purple spinels. The grains of coccolite, which have a rude cleavage approximating to a sub-conchoidal fracture, are isolated, or form aggregations, in the calcareous matrix: their surfaces are variously rounded and excavated, giving the grains an irregularly lobulated appearance. The occasional presence of planes, edges, and solid angles on their surfaces, renders it certain that the grains were originally crystals that have undergone superficial erosion by some dissolving agent. The spinels, which are in octahedrons, have been subject to a similar waste, though not to the same extent—only occasionally occurring more or less spherical, and with eroded surfaces.

In their irregular lobulated character, variety of aggregation, and scattered arrangement, the grains of coccolite strikingly resemble those of serpentine (" chamber casts") in the " acervuline" variety of "*Eozoon Canadense*," occurring in Canada. We take credit for being the first to point out a precisely similar agreement in the grains of chondrodite, pargasite, &c., common in the crystalline limestones of other places.*

But the specimen under notice shows other and additional characters, which still more clearly establish its " eozoonal" relationship.

When a slight portion of the matrix is removed by decalcification, the surface is seen to be crowded with slender cylindrical forms, more or less branching, often remarkably beaded, and arranged in all conceivable modes of grouping. They agree in every respect with the finest typical examples of the " canal system," as represented by Doctors Carpenter, Dawson, and Professor Rupert Jones.†

Associated with the latter are numerous specimens of the malacolite, divided by different sets of cleavage planes, the principal one giving them quite a lamellar structure. Occasionally others occur, approximating more or less to perfect prismatic crystals: but generally some of the angles, edges, and planes, have disappeared, or only traces are observable; so that they present the appearance of vermicular rods—

---

* " Quarterly Journal of Geological Society," vol. xxii., p. 209.

† See Dawson in " Quarterly Journal of Geological Society," vol. xxi., Pl. VII., figs. 3, 4, 5; Carpenter, ibid., Pl. VIII., fig. 5, *a*, *b*, *c*, and Pl. IX., fig. 5, *a*, *b*, *c*, *d*; Rupert Jones, " Popular Science Review," vol. iv., Pl. XV., figs. 6, 7, 8.

straight, bent, or twisted—nodulose, or irregularly excavated. These configurations exactly answer to certain of the so-called "stolons."*

It may be contended, by those from whom we differ on the question discussed in these pages, that the specimen belongs to an "eozoonal" rock. But, apart from its fatal agreement with other specimens of the kind in possessing the never-failing crystalline or metamorphic character—how, on such a view, are we to set aside the clear evidences of the "chamber casts" and the "stolons" having been originally crystals?

Besides, not only have these parts had a crystalline origin, but it is equally plain that the same conclusion must embrace the "canal system;" for it is impossible to detect any line of demarcation between the "stolons" and the latter. Dissolving action has, in the first place, converted the crystals of malacolite into the "stolons:" next the crystals were divided by cleavage, and eroded to such an extent that, in the state of the "canal system," they became reduced to mere skeletons.† Respecting the beaded character of the branching forms, we are strongly inclined to believe that it has resulted from the cleavage which transversely cuts the prisms: obviously the erosion would be deepest where it was present.

In no instance have we detected any traces of the "nummuline layer" on the grains—a deficiency we attribute to their component mineral, coccolite, not assuming the fine asbestiform structure which so eminently distinguishes serpentine in its change into chrysotile. There is often, however, a thin whitish granular coat investing the grains, sometimes so compact as to remain after they have been accidentally detached from the matrix.

Another specimen, which is from Amity, New York, consists of a similar calcareous matrix, holding spinel, chondrodite, serpentine, a micaceous mineral, and malacolite. One of the crystals of spinel is a compound octahedron, about two inches in its axial diameters, having part of its faces built up of minute triangular facets, and others, of small implanted octahedrons; both lying parallel to the faces of the large crystal. Numerous linear chinks, and irregularly formed cavities, separate the component triangular facets and octahedrons; and they are filled up with micro-crystalline calcite, similar to that of the matrix, enclosing malacolite. Decalcification brings out beautifully the last-named mineral, which assumes with wonderful exactness all the characters and modifications of the "stolons" and "canal system," as displayed in the Aker specimen; so that the description we have given of them would have to be repeated if we described those under consideration:

---

* See Carpenter, "Quarterly Journal of Geological Society," vol. xxi., Pl. VIII., fig. 3, Pl. IX., fig. 3; Jones, "Popular Science Review," vol. iv., Pl. XV., fig. 5.

† It may be hypothetically suggested that, in the final stage, the crystals have been totally dissolved. Malacolite consists, in round numbers, of silica 55·, lime 28·, magnesia 17· Assuming carbonic acid to have acted as the solvent, this substance might completely replace the silicic acid, and in this way change the basic constituent of the mineral; making calcite (or dolomite) a pseudomorph after malacolite.

and were it necessary to represent the latter, our representations would be close *fac-similes* of the figures, already referred to, which Dawson, Carpenter, and Rupert Jones, have published in their respective memoirs.

All the calcite of the specimen equally shows the same "eozoonal" structures; and that they have originated from the waste of crystals of malacolite. One example consists of a prismatic or longitudinally-cleaved mass of this mineral, having at one end the cleavage prisms diverging, losing their edges, and slightly branching; strikingly resembling the case figured in our first memoir,* and reminding us of the example of the "canal system," described by Dr. Carpenter as "consisting of parallel lamellæ disposed like the leaves of a book."†

Since it was first announced that we had determined "*Eozoon Canadense*" to be nothing more than a mineral production, we have all along felt that specimens would be found demonstrating more and more completely the truth of our conclusion: but we were certainly not prepared to meet with a large crystal of spinel, holding in its chinks and cavities typical examples of two of the essential features of this reputed organism; and these themselves possessing evidences indisputably testifying to their purely crystalline origin.

The Aker and Amity specimens show, what we have long suspected, as intimated here and there in the preceding Paper, that the arborescent forms ("canal system") may consist of other silicates besides serpentine. As to their being composed of anything else than a siliceous substance, we are not yet prepared to offer an opinion on the matter; though it must not be overlooked that similar forms, but on a comparatively gigantic scale, are common, consisting of carbonate of lime, in magnesian limestone, near Sunderland, in Durham. We have been led into this subject from observing a recent announcement, by Dr. Sterry Hunt, of *another* discovery in "*Eozoon Canadense*" (at Chelmsford, near Lowell, U. S.) of "the canals and tubuli of the calcareous skeleton filled, not with a silicate, but with carbonate of lime."‡ On seeing this announcement, we immediately wrote to Mr. Bicknell, of Salem, mentioned by Dr. Sterry Hunt, asking him to oblige us with specimens of the kind. Shortly afterwards we received from Mr. Bicknell, by sample post, a transparent section carefully prepared by himself, and a piece of the rock,—both labelled "Chelmsford." There were also specimens of "eozoonal" ophite from Newberryport, a neighbouring locality. In the latter, some of the structures are typically exhibited: the fibres of the "nummuline layer," however, are more confusedly arranged, and much longer than usual. In the former, the serpentine, of a pale-greenish colour, is in irregularly fractured pieces, separated from one another by unusually wide interspaces of calcite ("calcareous skeleton"), which contains

* "Quarterly Journal of Geological Society," vol. xxii., Pl. XV., fig. 17, *b*.
† "Intellectual Observer," vol. vii., p. 294.
‡ "Scientific Opinion," January 20, 1870, p. 45.

bundles of radiating crystals, also groups of vermicular branching forms ("canals and tubuli"): the "nummuline layer" is not well developed, being often represented by minute radiating aciculi. We have carefully tested the Chelmsford specimens, both by chemical reactions and polarized light, without, however, detecting any evidence of the "canal system" being else than siliceous; or of being composed of a substance identical with or related to its calcareous matrix.* Now, we cannot dispute the statement of Dr. Sterry Hunt; as probably some mistake may have been made in our specimens. We must, however, *in this case too*, complain of the very meagre and unsatisfactory account given of the "canals and tubuli" in the otherwise more detailed notice of the Chelmsford "Eozoon," published in "Silliman's Journal," p. 77, of January last. No evidence whatever is offered to show by what process the chemical nature of these parts was determined;—whether the conclusion that they are of the same composition as the "calcareous skeleton" was based on an examination by polarized light; or whether they do not consist of some soluble silica, or of a mixture of a carbonate and a silicate such as would be quite as readily acted upon by weak acid as their imbedding substance, especially if it be dolomite. We wish to call particular attention to the last point, as brief mention has already been made of a specimen of elæolite (a translucent variety, from Brevig), which, in consequence of its being an alkaliferous silicate of alumina (and there is no reason why such a compound may not occur in the Laurentian metamorphic marbles), was dissolved in weak acid. Another specimen, which we have lately subjected to the same process, was taken out of the solution in a partially digested state. When examined with the microscope, the residuum, which is in a slightly coherent condition, was found to consist of interlacing configurations, some of which, where well separated from the rest, bore no inconsiderable resemblance to the "canal system"—not, it is true, in its beautiful arborescent forms, but in the small crooked branching varieties, common to many Canadian examples. Prismatic cleavage, which elæolite eminently possesses, had evidently favoured the development of the configurations. They are transparent, rudely branching and anastomosing, showing rarely any cleavage edges or planes; these for the most part having been removed by the action of the acid.

Such a case as this clearly necessitates every point being duly considered before any conclusion can be drawn as to the chemical nature of the "canals and tubuli," should they appear not to have their ordinary composition. It also strikingly illustrates the view we have taken that these parts in typical "*Eozoon*" are merely the skeletons of fragments, or of crystals—respectively of serpentine or some other silicate—which remain after their waste had been arrested through changed conditions. Moreover, it testifies to our having succeeded in forming from elæolite, by the action of a weak solvent, configurations approximating to the rude varieties of the "canal system."

* We expect still to receive specimens, undoubtedly identical with those described by Dr. Sterry Hunt; when we hope to announce with more certainty the result of our investigations.

Description of the Figures in Plates XLI., XLII., XLIII., and XLIV.

Fig. 1.—Portion of a "chamber cast" from a transparent section of "eozoonal" ophite from Canada: to show the changes which serpentine undergoes. At first it is affected with fine linear separated divisions (*a*); which, through becoming more numerous, give rise to chrysotile (*b*): next is developed acicular chrysotile (*c*); which passes into "true nummuline" layer, i.e. with the fibres or aciculi separated. This section was presented to Dr. Rowney by Dr. Carpenter: as stated elsewhere, we decalcified it. Figures 2, 3, 4, 5, and 7 are from the same section. The parts are represented as seen by reflected light, and with a power magnifying 120 diameters.

Fig. 2.—"Chamber casts" separated by interpolated calcite (calcareous or "intermediate skeleton"); this being dissolved out, the cavity, A, has taken its place. The left "chamber cast," also the right one at the upper part, show fine linear separated divisions (*a*), which, when numerous, produce chrysotile (*c*). (By mistake this part is represented as consisting of what appear to be separated fibres; but they are in immediate contact). At *d*, *d*, the fibres represent "true nummuline layer." It will be observed that the fibres exactly correspond in direction with the linear divisions in the serpentine; which clearly proves that both kinds have one and the same origin. 210 diameters: opaque.

Fig. 3.—Lump of serpentine, breaking up into "chamber casts." The intervening spaces are filled with plates and "amorphous masses" (Carpenter) of granular flocculite; in some places this substance is rudely fibrous. At A (cavity) the flocculite is replaced by calcite (dissolved out), and the rude fibres by "true nummuline layer." 210 diameters: opaque.

Fig. 4.—Enlarged representation of a portion of Dr. Carpenter's section, showing the layers of "chamber casts" (*a*), and "intermediate skeleton" (*b*), obliquely divided by parallel cracks or fissures (*c*). Opaque.

Fig. 5.—Representation of one of the cracks (C), marked *c x* in fig. 4, lined with chrysotile (*c*), which is often in the state of "true nummuline layer" (*d*). Opaque. The fibres, it must be understood, are in close contact, though apparently not so in the figure.

Fig. 6.—Vein or crack (intersecting serpentine in a slab of Connemara ophite), filled with chrysotile in its various modifications. The upper portion of the vein passes through "chamber casts;" and here it consists of both juxtaposed (*c*) and separated (*a*) aciculi: the last variety, which is undistinguishable from "true nummuline layer," is also seen on the adjacent segmented granules, marked *d*. On entering the vacancy A, the vein, here typical chrysotile, becomes divided into two portions; the division, *d*, being separately acicular; and the other, *c*, asbestiform.

Fig. 7.—Decalcified portion of "intermediate skeleton," containing plates, rods—branching and simple—characteristic of the "canal system;" also "amorphous masses" (A, B) or flocculent modifications of the latter. At B *x*, the serpentine is seen changing into the above. (This figure fails to give a proper idea of the changes exhibited by the serpentine). Opaque.

Fig. 8.—Portion of serpentine in a specimen of decalcified ophite from "Neybiggen," divided by lamellar (*a*) and fibro-lamellar (*b*) cleavages. These two divisional structures break the serpentine into prisms; which, losing their edges, become vermicular and separated (*c*), at the same time changing from green to white. In the latter state the configurations closely resemble the simple "definite shapes" of the "canal system." Opaque: 120 diameters. Figure 8, *x*, represents a transverse section of a prism, formed by the two sets of cleavage (imperfectly delineated, however).

Fig. 9.—Portion of a decalcified vein or crack intersecting serpentine in a slab of Connemara ophite. Both sides are lined with various modifications of chrysotile,—asbestiform at *c*, and separately acicular at *d*. The bottom of the vein (darker coloured) is filled with fibrous calcite: the same substance occupied the spaces between the two fringes of chrysotile, also the openings between the separated aciculi, before decalcification. Opaque: 60 diameters.

Fig. 10.—Grains ("chamber casts") of pale-green serpentine (represented decidedly too dark) in a decalcified specimen of Liassic ophite from the Isle of Skye, presented to us by Professor Harkness. The grains are for the most part invested with "true nummuline layer," which in some places is asbestiform. The grain, A x, (which is below the level of the others) has its surface quite hispid with separated aciculi. Opaque: 210 diameters.

Fig. 11.—Transparent siliceous "definite shapes" (only made properly visible by means of Webster's condenser, with graduating diaphragms) of the "canal system," partly imbedded in calcite. The matrix having been decalcified a little, the "definite shapes" project above its surface: the thin end of the long one is still imbedded, as shown by the characteristic rhombohedral and macrodiagonal cleavages of the calcite passing over it. 120 diameters. N. B.—Figure 11 x is cancelled.

LVIII. — The Ruins on Ardillaun, Co. Galway. By G. Henry Kinahan, F. R. G. S. I.

[Read November 8th, 1869.]

Ardillaun, or High Island, lies a short distance from the coast of Iar-connaught, and on it are the ruins of an ancient ecclesiastical colony. Of this island O'Flaherty, the historian, thus writes: "Anciently called Innishiarther, i. e., the West Island, it is inaccessible but on calm, settled weather, and so steep that it is hard, after landing in it, to climb to the top." He afterwards states that the abbey was founded by St. Fechin of Omay, and that eleven holy hermits are buried here; while Hardiman in his notes gives the names of these men.*

The ruins of the ancient structures are situated at the S. W. end of the island; an irregular peninsula being enclosed by a wall extending from the cliff over a coose that enters the island on its western shore, to the cliff over another coose that runs north-westward into the south part of the island; and inside this wall seem to have been all the principal buildings.

Between the two cooses is a small lake, on the north shore of which the settlement was erected. The church was enclosed within a wall or cashel, and associated with it are other structures, with the principal clochaun.

The accompanying sketch plan (*map*, Pl. XLV.), shows the cooses, lakes, and wall, of all these buildings whose sites can now be traced.

This island, about twenty-four years ago, was part of the Connemara property of the Martins; while it belonged to that family the ruins are said to have been protected, and to have been in a good state of preservation. Unfortunately, when it passed out of their hands it came into that of an absentee English proprietory, and during the famine and subsequent years (1846 *et seq.*) many of the most interesting of the carved stones were carried away. Since then no care has been taken to preserve the ruins, they being allowed to be destroyed by persons hunting rabbits; while the crosses and the other carved stones have been knocked

* O'Flaherty's "History of Híar or West Connaught," pp. 114 and 115.